
ASARCO EAST HELENA SMELTER COVER SYSTEM DESIGN

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February 2008

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ASARCO EAST HELENA SMELTER COVER SYSTEM DESIGN

1.0 INTRODUCTION

On May 5, 1998, ASARCO LLC (Asarco) and the United States Environmental Protection Agency (EPA) entered into a Consent Decree (RCRA Consent Decree, U.S. District Court, 1998) to initiate the corrective action process in accordance with the Resource Conservation and Recovery Act (RCRA) and the Clean Water Act (CWA). As part of the RCRA Consent Decree, Asarco prepared several site investigation documents including:

- RCRA Current Conditions/Release Assessment (CC/RA) (Hydrometrics, 1998)
- Interim Measures Work Plan, East Helena Facility (Hydrometrics, 1999)
- RCRA Facility Investigation (RFI) Work Plan (Hydrometrics, 2000) and
- Phase I RCRA Facility Investigation Report (Asarco Consulting Inc. (ACI) 2003, revised 2005).

A complete listing of RCRA Consent Decree documents is contained in the Phase I RCRA Facility Investigation (RFI) Site Characterization Report (ACI, 2003).

The Phase I RFI report characterized surface soils, subsurface soils, groundwater and surface water on the East Helena Plant site. It identified the presence of arsenic plumes that begin on the plant site and extend into the City of East Helena. It also evaluated the potential for impacts of site soils on groundwater. Based on data presented in the RFI report, elevated levels of arsenic and metals are present at depth in many areas on the plant site and levels remain elevated below the water table in some source area locations.

Since completion of the Phase I RFI report, numerous interim measures have been completed and several supplemental interim measures are expected in 2008 and subsequent years.

Completed interim measures focused on identified source areas and their potential to impact off-site private and public water supplies. Post Phase I RFI interim measures included:

- Augmentation of the existing long-term monitoring program to refine information on the off-site plume and its potential for impacting private and public water supply wells and systems.
- Isolation of identified source areas of contaminants to groundwater by construction of slurry walls and temporary cover systems in the former acid plant sediment drying area and in the former speiss-dross area.

Additional interim measures are expected to address plant site soils and groundwater in 2008 and subsequent years. These measures are expected to include:

- Sampling and selected removal of exposed soil located in the foot prints of demolished structures, that have levels of constituents of concern that are considered elevated compared to existing site wide data. The foot print areas have been and continue to be exposed as a result of cleaning and demolition of site structures, which is being conducted in accordance with a 2007 Administrative Order on Consent between Asarco and the Montana Department of Environmental Quality (MDEQ). This work is described in the plan titled, "2007 Cleaning and Demolition Project, Asarco East Helena Plant" (Hydrometrics, May 2007 and August 2007 Amendment). The proposed program for sampling exposed soil in the foot prints of demolished structures and for remediation of those with elevated levels of constituents of concern is described in the "Demolition Foot Print Exposed Soil Area Sampling Excavation and Confirmatory Sampling Work Plan" (Asarco, 2008). This Soil Sample Work Plan will be submitted separately, but will augment this Cover System Design report.
- Supplemental characterization of on-site and off-site groundwater for elevated concentrations of constituents of concern, particularly arsenic and selenium. This supplemental work includes expansion of the existing monitoring well network and groundwater monitoring program.

- Evaluation of future groundwater interception, treatment and discharge systems to limit off-site migration of arsenic and selenium.

The Phase II RFI will complete the site characterization process. The Phase II RFI will address any remaining characterization of surface and subsurface soils, and groundwater on the site. It will also include a site-specific assessment of human health risks and ecological risks. Based on data and conclusions presented in the Phase I and Phase II RFI reports, a Corrective Measures Study (CMS) will be prepared to evaluate and present the final remedy for the East Helena Site. It is expected many of the interim measures that have been or will be implemented at the East Helena Site will be incorporated as part of the final remedy presented in the CMS.

This Cover System Design Report presents a conceptual design for a site facility cover system for the East Helena plant. This system is presented as an interim action that ultimately will be a part of the final permanent remedy when remaining Consent Decree activities, including the Phase II RFI and the CMS, have been completed, and the final remedy for the site has been selected. Based on data presented in the RFI, soils with elevated metal concentrations appear to be wide spread throughout the plant site area and appear to extend too deep for site-wide treatment or removal to be practical. As a result, a site capping or cover system will be a component of any final remedy that is ultimately implemented for the site.

As noted by EPA: Cover (or cap) systems at containment sites are used to minimize the infiltration of water into the contaminated material and to serve as protective barriers to isolate contaminants from the public and the environment. EPA encourages flexibility in the design of covers for all waste sites. Covers can range from a simple soil or asphalt layer to protect people from contact with the contaminants, to multi-layered composite caps recommended for more demanding situations. (EPA, 2002)

Asarco proposes to place a cover system over the East Helena plant site in order to address the environmental issues presented in the "Remedial Investigation and Feasibility Study"

(RI/FS, Hydrometrics, 1990) and the “RCRA Facility Investigation” (RFI, ACI, 2003). When combined with a systematic approach of facility cleaning and structural demolition, the cover system provides permanent site stability and closure. Site elements or media for which environmental concerns may be at least partially addressed by a site cover system include:

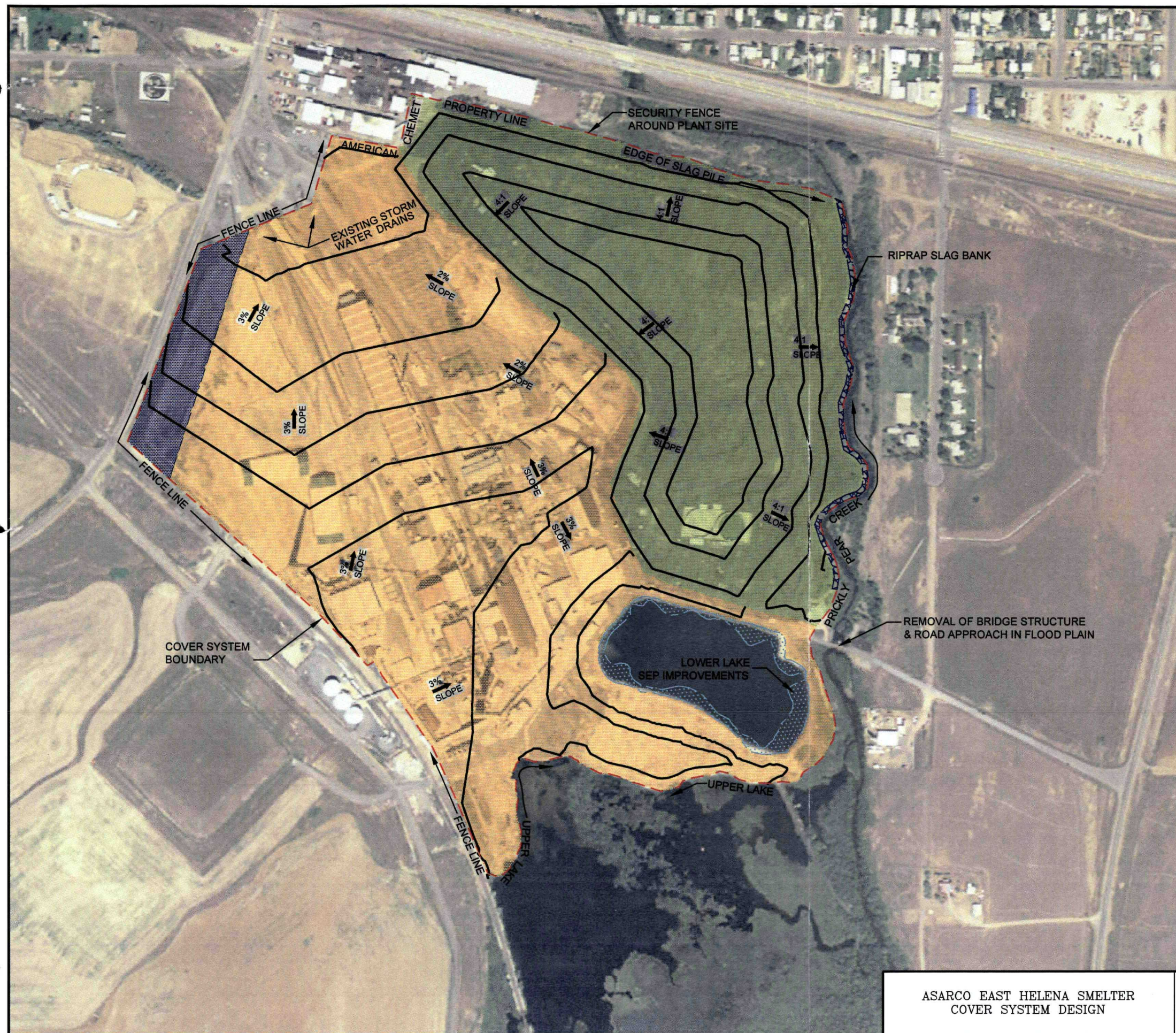
- Groundwater
- Surface water
- Surface and subsurface soil and
- Slag pile.

Although this list includes water, the cover system targets the contribution that site soils and waste products, such as slag, have on the site media listed above. Asarco’s goals for the cover system include:

- Minimize the potential for infiltration and contact of facility soils with groundwater and surface water
- Isolate the facility from the public and surrounding environment and
- Minimize the potential for erosion on the facility and the potential for the mobilization of sediment to off-facility areas.

As shown in Figure 1-1, the cover system will include nine (9) primary work elements. These include:

- Grade the site to promote drainage.
- Remove contaminated soils on the west boundary portion of the plant and incorporate under a multi-layered cover system.
- Cover the slag pile.
- Cover the remaining portions of the site where soil removal will not be conducted because complete removal is not feasible or practical.



SCALE
(In Feet)
0 400



LEGEND



PROPOSED LOCATION OF CONTAMINATED SOIL REMOVAL TO ACHIEVE EPA'S PREFERRED CLEANUP ALTERNATIVES.



PROPOSED SITEWIDE MULTILAYERED COVER SYSTEM



PROPOSED SLAG PILE EVAPOTRANSPIRATION COVER SYSTEM



LOWER LAKE SEP IMPROVEMENTS



SLOPE DART - SHOWS DIRECTION OF RUNOFF AND SLOPE ANGLE



SECURITY FENCE

NOTES:

THE COVER SYSTEM WILL INCLUDE NINE (9) PRIMARY ELEMENTS. THESE INCLUDE:

- GRADE THE SITE TO PROMOTE DRAINAGE.
- REMOVE CONTAMINATED SOILS ON THE WEST BOUNDARY PORTION OF THE PLANT AND INCORPORATE UNDER A PLANT WIDE COVER SYSTEM.
- COVER THE SLAG PILE
- COVER THE REMAINING PORTIONS OF THE SITE WHERE SOIL REMOVAL WILL NOT BE CONDUCTED BECAUSE COMPLETE REMOVAL IS NOT FEASIBLE OR PRACTICAL.
- MODIFY EXISTING STORM WATER STRUCTURES TO CONVEY WATER OFF SITE
- ARMOR PRICKLY PEAR CREEK
- IMPLEMENT THE SUPPLEMENTAL ENVIRONMENTAL PROJECT (SEP) FOR LOWER LAKE
- REMOVE THE EAST BRIDGE AND ASSOCIATED FLOODPLAIN ENCROACHMENTS AND
- SECURE THE SITE

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

PLANT COVER SYSTEM SITE PLAN

FIGURE

1-1

- Modify existing storm water structures to convey water off site.
- Armor Prickly Pear Creek.
- Implement the Supplemental Environmental Project (SEP) for Lower Lake.
- Remove the east bridge and associated floodplain encroachments.
- Secure the site.

This document and its appendices contain Asarco's proposal for general design and construction of the cover system, which will be deployed in stages following cleaning and demolition of the East Helena Smelter. It also presents detailed design for construction of a portion of the cover system in 2008 (see Section 9.0). Design of source area excavations, off-site remediation, source area isolation barriers, the proposed reactive barrier, and other groundwater migration controls are not addressed in this document.

1.1 PROJECT GUIDANCE

Three published reports comprise the guidance for this project. These include:

- Comprehensive Remedial Investigation/Feasibility Study (RI/FS, Hydrometrics, 1990)
- Current Conditions Release Assessment (CCRA, Hydrometrics, 1998) and
- RCRA Facility Investigation (ACI, 2003).

The proposed cover system seeks to address specific environmental issues raised in these reports, as well as incorporate EPA guidance for RCRA cover systems, including:

- Reusing Superfund Sites, Commercial Use Where Waste is Left in Place, 2002
- Design and Construction of RCRA/CERCLA Final Covers, May, 1991
- Design, Construction, and Maintenance of Cover Systems for Hazardous Waste, and Engineering Guidance Document, November, 1987 and
- Evaluating Cover Systems for Solid and Hazardous Waste, September 1982.

1.2 SITE BACKGROUND

The Asarco East Helena Smelter site has been described in detail in the RI/FS, CCRA, and the RCRA Facility Investigation. This report will not repeat information that has already been submitted in these other reports, but will seek to summarize performance standards that the design must meet and to explain how each element of the proposed project supports the objectives of these previous works.

1.3 COVER SYSTEM BOUNDARY

Figure 1-1 shows the extent of the cover system that Asarco is proposing for the site. From the corner of the Asarco plant nearest American Chemet property, the cover system boundary follows the fence line around the south side of the plant to Upper Lake, where it follows the edge of Upper Lake until it reaches the east end of the disturbed area between Upper Lake and Lower Lake, referred to as Tito Park. In order to allow enough depth above the water table to construct the cover system layers and anchor the liner(s) in a trench, the boundary will be kept back from the pond edges a sufficient distance to place the cover system surface at an elevation approximately 4 feet above the lake levels. After crossing Tito Park, the proposed boundary extends on around the east side of Lower Lake until it intersects Prickly Pear Creek. The boundary will follow the west bank of the creek to the north and then the west, encompassing two sides of the slag pile. Where the creek flows under Highway 12 on the north side of the plant, the boundary will follow American Chemet's property line back to the plant fence and its starting point in this discussion.

Although most the area within this boundary will receive a cover, there is a portion within the boundary along the west side of the plant where it may be practical to remove contaminated surface soils as part of the grading needed to promote good site drainage. We anticipate that the depth of cut in this area may result in soils that are clean enough to meet remediation standards and not require the cover. These standards are yet to be determined, but for the purposes of this document, EPA's cleanup goals for underdeveloped land for commercial/industrial use in the East Helena area have been assumed. This area is shown in purple on Figure 1-1. Therefore, the project boundary may vary from the cover system boundary in this area.

2.0 PERFORMANCE STANDARDS

As stated in Section 1.0, cover systems at containment sites are used to minimize the infiltration of water into the contaminated material and to serve as protective barriers to isolate contaminants from the public and the environment (EPA, 2002). More specifically, the proposed cover system is designed to:

1. Prevent direct contact of people, animals, and surface water with contaminated soils and slag.
2. Prevent contaminated soil and slag from being wind-blown.
3. Minimize water infiltration.
4. Function with minimum maintenance.
5. Promote drainage while guarding against erosion or abrasion of the cover.
6. Minimize settling and subsidence so that the cover's integrity is maintained.

The following Performance Standards are parameters by which the success of design and construction of the cover system for the East Helena Plant can be measured. They contain criteria that must be satisfied to achieve the remediation goals set for each project element. The project guidance documents were reviewed for relevant project standards. Performance standards were identified from guidance documents for each of the cover system project elements.

2.1 GRADE SITE TO PROMOTE DRAINAGE

One of the goals of the cover system is to minimize the infiltration of water into the contaminated material. In order to accomplish this goal, Asarco proposes to grade the site to promote drainage and prevent surface water from pooling. EPA recommends that the final surface of soil be graded at a slope between three and five percent (EPA, 1991). Any liners used in construction of the cover system should also be constructed with sufficient slope to promote drainage and keep the depth of water that pools on their surface to a minimum. EPA recommends a minimum slope of three percent for liners (EPA, 1991). However, there are a

few areas on the site where a grade slope of three percent is not achievable without placement of a significant depth of fill.

Deep fill areas are not desirable because of the increased risk of settlement under the cover system. Settlement can put stress on liners and create low areas where water will pool despite the slope. Therefore, Asarco proposes the following performance standard:

- Limit depths of fill beneath the cap to 10 feet.
- Use a minimum slope of three percent for site grading except where this slope would result in fill areas that exceed 10 feet.

Use of a geosynthetic drainage layer above the cover system liner will compensate for some degree of reduction in slope by providing better drainage above the liner than if a sand drain were used, as recommended by EPA (1991). Therefore, Asarco proposes the following performance standard:

- In areas where the target slope of three percent will result in depth of fill exceeding 10 feet, establish a minimum slope of one percent as the performance standard for grading.

When used with both a geosynthetic liner and drainage layer, modeling of the flow from the drainage layer with a minimum slope of one percent was found to remove nearly as much water as with a three percent slope and effectively reduced the depth of ponding on the underlying liner. Further discussion of the drainage layer, including modeling results is presented in Section 4.1.2.

2.2 REMOVE CONTAMINATED SOILS TO EPA'S CLEANUP GOALS FOR UNDEVELOPED LANDS

To achieve performance standards for site grading and drainage, there may be areas near the cover system boundary where surface soils will need to be excavated. Surface soils in these areas will be removed to achieve the cleanup goals for undeveloped lands for

commercial/industrial use set forth in EPA's Proposed Plan for residential areas and undeveloped lands within the East Helena Superfund site (EPA, 2007). Areas of the plant that achieve EPA's cleanup goals through soils excavation and removal will not be included under the cover system. EPA's preferred cleanup goals for undeveloped land for commercial/industrial use include:

- Lead – where soil lead concentrations exceed 1300 mg/kg, soils will be excavated until all remaining lead concentrations, after excavation, are less than 1300 mg/kg.
- Arsenic – where soil lead concentrations exceed 270 mg/kg, soils will be excavated until all remaining lead concentrations, after excavation, are less than 270 mg/kg.

Figure 1-1 suggests an area of the site, shown in purple, where this performance standard may be applicable. Soils removed from these areas will be incorporated as fill under the multi-layered cover system.

2.3 COVER THE SLAG PILE

The effect of the slag pile on groundwater and surface water was evaluated as part of the 1990 Comprehensive RI/FS. Based on the results of the evaluation, the RI/FS concluded that the potential for impacts to groundwater and surface water from slag is low. The reasons for this conclusion was the fact that measured infiltration into the slag pile was very low, and tested leachate showed a low potential for metals mobility from slag. The EPA did not issue a CERCLA Record Of Decision (ROD) that addressed the slag pile, and as a result specific remedial action for this feature has not been specified.

However, recent groundwater data collected in fall 2007 suggest a source of elevated selenium concentrations in groundwater beneath the slag pile. Although recent data also show the slag collected from surface locations have low metal concentrations and low leachate potential for selenium, a potential source of selenium at the base of the slag or immediately below the slag pile is suggested by the fall 2007 groundwater quality data. Similar to plant site soils, the potential source of selenium under the slag pile is too deep for removal methods to be practical, and Asarco and EPA are evaluating control of selenium

migration by groundwater control and/or treatment methods. Although a final remedy has yet to be determined in accordance with the Consent Decree process, it is expected capping of the slag pile as an interim measure will be incorporated into the final remedy. Therefore, Asarco proposes these performance standards for the slag pile cover system:

- Prevent direct contact of people and animals with slag.
- Minimize the potential for infiltration of water through the slag pile.
- Prevent slag from being wind-blown and eroded.
- Stabilize slag pile.

An Evapotranspiration (ET) cover system is proposed for the area of the plant site shown in green on Figure 1-1. Asarco proposes the following performance standards for this cover system:

- Provide a 42-inch layer of engineered cover soil and a 6-inch layer of soil capable of sustaining plant species, and a good cover of vegetation that will allow runoff but prevent erosion.

2.4 COVER THE MAIN PLANT FACILITY AREA

For hazardous waste management units, EPA recommends that the final cover consist of, from bottom to top:

1. A low hydraulic conductivity geomembrane or soil layer.
2. A soil or geosynthetic drainage layer.
3. A soil layer with either vegetation or armor.

Therefore, except in areas that can be practically cleaned up to achieve EPA's preferred cleanup alternatives by soil removal and the slag pile, Asarco proposes to place a multi-layered cover system, similar to the one on Asarco's Corrective Action Management Unit

(CAMU, Hydrometrics, 2007b), over the portion of the site shown in yellow on Figure 1-1. Asarco proposes the following performance standards for this cover system:

- Provide a low hydraulic conductivity layer, covering the soil, concrete and slag, composed of a composite of geosynthetic clay liner on the bottom and an appropriate geomembrane on the top.
- Provide a drainage layer over the liner composed of a geosynthetic drainage net.
- Provide a 36-inch layer of cover soil that includes 6-inches of soil capable of sustaining plant species, and a good cover of vegetation that will allow runoff but prevent erosion.

2.5 CONSTRUCT STORM WATER UTFALLS

In order to function properly, the cover system drainage layer will need a place to freely discharge. Asarco proposes to use existing storm water system intakes to accept this storm water from the cover system. The existing storm water system will provide a level of collection for storm water until it can be treated in the current water treatment plant. It is anticipated that, following a finite period of time, the storm water from the cover system will eventually meet discharge requirements without any treatment.

2.5.1 Design Flows

Design of the cover system will be based on:

- Runoff volumes and flow rates from at least the 25-year, 24-hour storm event for design of drainage features and
- Rare events up to the 100-year storm for protection of the cap from damage caused by erosion.

2.5.2 Water Quality

Storm water quality shall meet existing discharge standards (ASARCO, 2006).

2.5.3 Storm Water Controls

Until construction of the cover drainage system is complete, storm water on the site will continue to be collected as it is now. In addition, storm water controls will incorporate the substantive requirements of the Montana DEQ Storm Water Construction Guidance document.

2.6 ARMOR SLAG PILE ADJACENT TO PRICKLY PEAR CREEK

There is direct contact and erosion of the slag pile where it forms steep sided banks adjacent to Prickly Pear Creek. As a result, Asarco proposes the following performance standard for this project element:

- Armor the slag pile stream bank to prevent erosion due to flows up to the 100-year flow event in Prickly Pear Creek.

2.7 IMPLEMENT THE SEP FOR LOWER LAKE

Performance Standards for the Lower Lake SEP (Hydrometrics, 1997) include:

- Identify and improve site conditions that have precluded the establishment of vegetation on barren shorelines of Lower Lake and portions of the Upper Lake north and west shorelines.
- Fill portions of the Lower Lake perimeter to form an irregular shoreline to naturalize the site, create riparian habitat for adapted vegetative communities, expand and enhance wildlife habitat, and potentially improve water quality.
- Grade the area between Upper and Lower Lakes to form naturalized topographical contours to enhance upland vegetative and wildlife habitat.
- Plant vegetative screens along portions of north and west Upper Lake perimeter areas and between Upper and Lower Lake to enhance wildlife habitat.

An additional Performance Standard is proposed for implementation of the SEP:

- Establishment of constructed flow corridors through the area between Upper and Lower Lakes to short circuit flow through the fill in this area and directly improve water quality in Lower Lake. The goal of this action is to improve Lower Lake water quality enough to meet CERCLA Standards for this pond established in the 1989 Process Ponds ROD (EPA, 1989).

2.8 IMPLEMENT SITE SECURITY AND MAINTENANCE

To ensure site security and maintenance of the entire cover system and all its components, Asarco proposes the following performance standards:

- Establish a security fence around the perimeter of the cover system.
- Implement a maintenance plan to ensure the integrity of the cover system.

2.9 SUMMARY OF PERFORMANCE STANDARDS

In order to prevent direct contact of people, animals, and surface water with contaminated soils and slag, prevent contaminated soil and slag from being wind-blown, minimize water infiltration, function with minimum maintenance, promote drainage while guarding against erosion or abrasion of the cover, and minimize settling and subsidence so that the cover's integrity is maintained, the following is a summary of Performance Standards that have been used for design of the proposed grading and capping project:

1. Limit depths of fill beneath the cover system to 10 feet.
2. Slope the site to promote drainage.
 - a. Use a minimum slope of three percent for site grading except where this slope would result in fill areas that exceed 10 feet.
 - b. In areas where the target slope of three percent will result in depth of fill exceeding 10 feet, establish a minimum slope of one percent.
3. Remediate areas of the plant without a cover system where, after soil removal, lead and arsenic concentrations meet EPA's preferred cleanup alternative goals.

4. Prevent direct contact of people and animals with slag and contaminated soils.
5. Prevent slag and contaminated soils from being wind-blown and eroded.
6. Stabilize slag pile.
7. Minimize the potential for infiltration of water through the slag pile by providing a ET cover system that includes:
 - a. A 48-inch layer of cover soil that includes 6-inches of soil capable of sustaining plant species, and a good cover of vegetation that will allow runoff but prevent erosion.
8. Other than on the slag pile and in areas where contaminated soil has been removed to EPA's preferred cleanup alternative goals, provide a multilayered cover system that includes:
 - a. A low hydraulic conductivity layer composed of a composite of geosynthetic clay liner on the bottom and a geomembrane on the top.
 - b. A drainage layer over the liner composed of a geosynthetic drainage net.
 - c. A 36-inch layer of engineered cover soil that includes 6-inches of soil capable of sustaining plant species, and a good cover of vegetation that will allow runoff but prevent erosion.
9. Design drainage features based upon runoff volumes and flow rates from at least the 25-year, 24-hour storm event.
10. Protect the cover system from damage from rare events up to the 100-year storm.
11. Meet existing storm water discharge standards.
12. Incorporate the substantive requirements of the Montana DEQ Storm Water Construction Guidance document.
13. Armor the slag pile stream bank to prevent erosion due to flows up to the 100-year flow event in Prickly Pear Creek.
14. Implement the Lower Lake SEP, including:
 - a. Identify and improve site conditions that have precluded the establishment of vegetation on barren shorelines of Lower Lake and portions of the Upper Lake north and west shorelines.

- b. Fill portions of the Lower Lake perimeter to form an irregular shoreline to naturalize the site, create riparian habitat for adapted vegetative communities, expand and enhance wildlife habitat, and potentially improve water quality.
 - c. Grade the area between Upper and Lower Lakes to form naturalized topographical contours to enhance upland vegetative and wildlife habitat.
 - d. Plant vegetative screens along portions of north and west Upper Lake perimeter areas and between Upper and Lower Lake to enhance wildlife habitat.
 - e. Establish constructed flow corridors through the area between Upper and Lower Lakes to short circuit flow through the fill in this area and directly improve water quality in Lower Lake.
15. Install a fence to secure the site.
16. Establish a program to maintain the cover system.

The following sections describe the proposed site cover project in more detail and how implementation of these performance standards will ensure that the site covering system is protective of human health and safety and of the environment. The protection of human health and the environment will be addressed further in the RFI Phase II risk assessment.

3.0 SOIL AND SLAG CONTAINMENT

The proposed cover design for the site includes engineered containment of soils, concrete, and slag. As part of Montana Administrative Order on Consent, the remaining identified structures on the site will be cleaned and demolished. The demolition debris will be either recycled or placed into the Phase 2 CAMU cell. When complete, the site surface will be composed primarily of soil, slag, and either Portland Cement (PCC) or Asphalt Concrete (AC). As shown in Figure 3-1, the most notable feature that will be left following cleaning and demolition is the 70-foot high slag pile that occupies nearly half the plant site on its north and east sides. Currently, the sides of the slag pile slope at approximately 1.5 to 1 (horizontal:vertical). This slope is too steep to cover with soil and expect the cover system to remain stable. Therefore, these slopes will be pulled back before being covered.

Reducing the side slopes of the slag pile will generate a quantity of slag that will need to be placed under the site cover system. Figure 3-1 shows the proposed grading plan for placement of the excavated slag under the site cover system. As explained in the following sections, the proposed grading plan is designed to provide drainage for the cover system while keeping the thickness of the engineered fill to a minimum. Engineered containment systems generally do not have serious differential or general subsidence, or gas production (EPA, 2002). However, a portion of the site between Upper and Lower Lakes and the plant poses some concern related to general subsidence and gas production.

3.1 SETTLEMENT

The East Helena Plant site has had numerous geotechnical investigations related to facility construction that have shown the site surface and sub-surface to be composed of materials having high bearing strengths that will not be susceptible to subsidence. For instance, in their geotechnical investigation for construction of the Scrubber Water Treatment Facility, GMT Consultants (1991) recorded blow counts of near 100 (per foot), which is the maximum possible, down to a depth of 12 feet. Blow counts exceeding 50 indicate a very dense soil with bearing strengths exceeding 50 tons-per-square-foot (tsf) for cohesionless soils



(Hunt, 1984). The graded fill and cover system will place a maximum distributed load of less than one (1) tsf. In most cases, the structures that once occupied the site placed more stress on the underlying soil than the graded fill and cover system will. Therefore, settlement due to the weight of the fill and cover system is not a concern over most of the site. However, there may be some potential for settlement within the layer of slag that is proposed as fill for grading and drainage.

Slag has been used successfully for grading and drainage under temporary covers throughout the site. It is a strong, dense material and may be primarily responsible for the high blow counts recorded at the site. Stabilizing the sides of the slag pile will produce large quantities of slag that will be used as fill on the site to achieve grades that promote drainage from the cover system. However, it will not be possible to specify a compaction goal for the slag in the typical manner used for soil fill. Proctor tests are meaningless for slag, and its relative density will be a continually changing target because the particle size and specific gravity of the material will be continually changing. Therefore, the proposed compaction specifications are performance and not outcome driven. They specify the number of passes, equipment requirements, and lift thickness to be used, but do not specify a required relative density that must be achieved. For this reason, the total depth of fill used to establish grading for the cover system has been kept to a minimum in order to ensure that if settling of the fill occurs, the amount of settlement will not compromise the cover system. The proposed grading results in a maximum depth of fill of just 10 feet, while allowing a slope of three percent to be established for the cover system over most of the site.

As previously noted, the portion of the site between Upper and Lower Lakes and the plant poses some concern related to general subsidence. This area is composed not of slag mixed with native soil like the rest of the site, but of a mixture of random fill that years ago was placed in this locale and that in some places is quite deep. During design of the Spray Dryer facility, the geotechnical investigation found this area to have layers of weak material that may settle under significant loads. Therefore, the grading plan includes little if any fill in this area of the site.

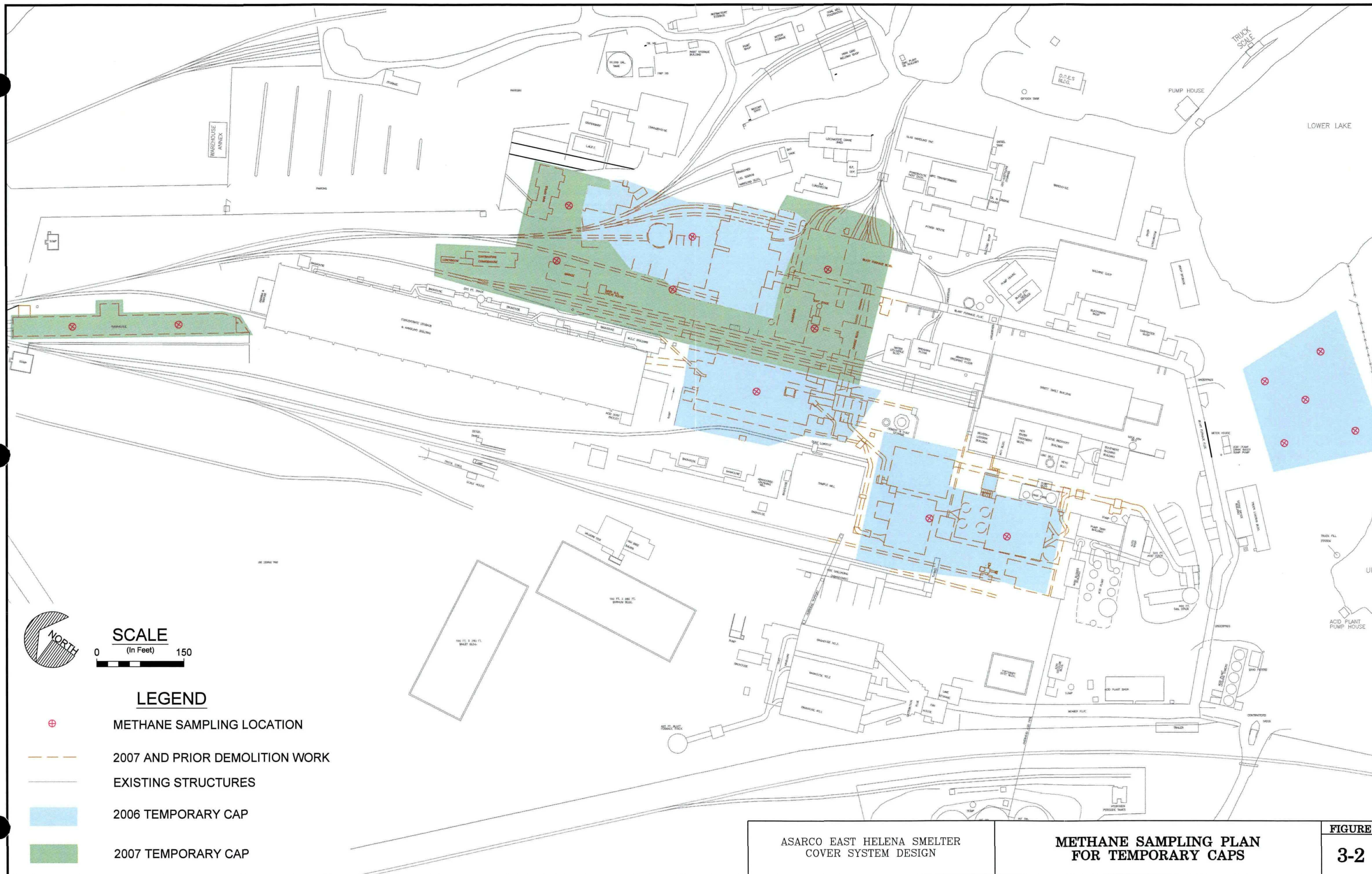
3.2 GAS GENERATION

During 2006 and 2007, Asarco conducted interim remediation actions including the cleaning and demolition of buildings and structures located on the site. After the demolition waste was removed, temporary caps consisting of geomembrane liners were placed over the site to prevent erosion of any potentially contaminated material from wind or rain and to prevent infiltration of water. If any materials remain on the site, such as timbers or wood waste, that could create the potential for production of methane, it would now be collecting under these temporary caps. To ensure that any areas that are actively producing methane receive appropriate consideration during design of the final cover system, an investigation will be conducted for the purpose of determining any areas on the site where methane may be detected beneath the temporary liners. The goals for this investigation include:

1. Determine if methane is present beneath the existing temporary liners
2. Measure and map the level and aerial extent of subsurface methane gas and
3. Repair liner perforations required to sample methane.

To get a general idea of whether methane is being generated below the ground surface and trapped beneath the temporary liner, samples will be collected under every 100,000 square feet of liner as shown in Figure 3-2. Because the area between Upper and Lower Lakes is expected to have a greater potential for methane generation, samples in this area will be collected under every 10,000 square feet of liner. In all, sixteen locations will be sampled for methane, carbon dioxide, oxygen, and nitrogen content.

The gas beneath the liner will be sampled using a portable landfill gas meter. A small slit will be made in the liner with a sharp knife, and the sampling tubing attached to the landfill gas meter will be inserted beneath the liner through the slit. The slit will then be sealed with duct tape to prevent the introduction of atmospheric gases during sampling. After the meter and associated pump are started, the gas readings will be allowed to stabilize before the results are recorded. After sampling, the sample port will be repaired using Griff Tape, an adhesive-backed liner repair sealing tape provided by the liner manufacturer.



Once this data are analyzed, it will define if gas extraction systems are necessary and the extent of gas formation. It may be possible that additional samples may be necessary to better define the nature and extent of volatile gas production.

4.0 COVER SYSTEM

Several cover system types will make up the overall cover system of the facility. The majority of the site, shown in yellow on Figure 1-1, will utilize a multi-layered cover system. The slag pile, shown in green on Figure 1-1, will be covered with an evapotranspiration cover system. An area in the northwest corner of the site, shown in purple on Figure 1-1, will be cleaned up to achieve EPA's preferred cleanup alternative through soil excavation and removal and will be remediated with a vegetative cover.

4.1 MULTI-LAYERED COVER SYSTEM

For hazardous waste management units, EPA recommends that the final cover consist of, from bottom to top:

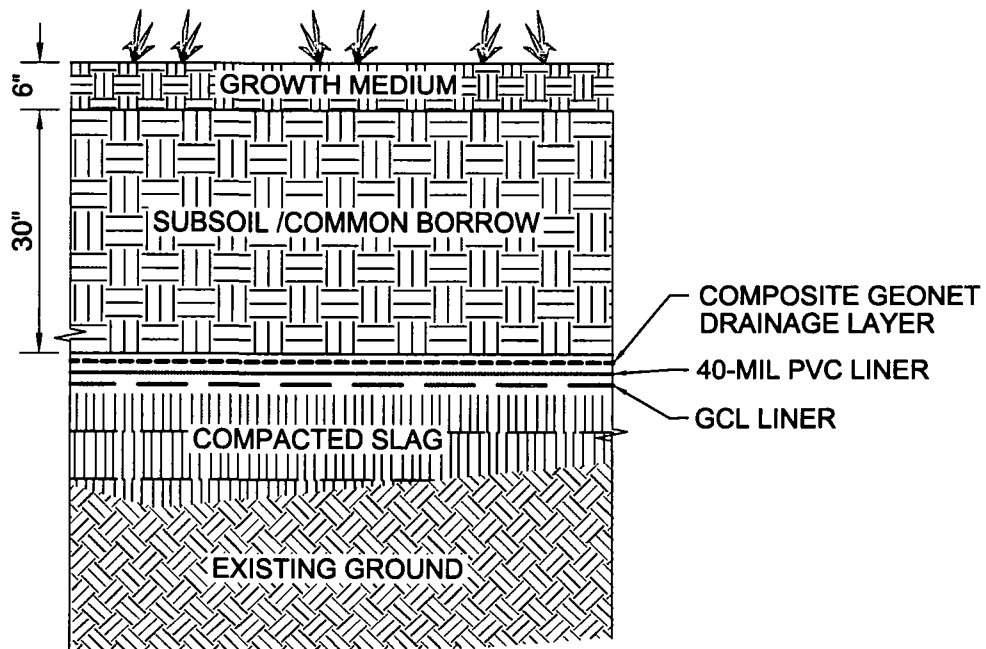
1. A low hydraulic conductivity geomembrane or soil layer.
2. A soil or geosynthetic drainage layer.
3. A soil layer with either vegetation or armor.

As shown in Figure 4-1, from bottom to top the multilayered cover system being proposed for a majority of the site includes a hydraulic barrier covering the slag fill, a drainage layer, cover soil, and erosion protection on the surface.

4.1.1 Hydraulic Barrier

The most common of the three types (hydraulic barriers), use low-permeability material to impede the downward migration of water. They are usually multi-layered cover systems that typically incorporate geomembranes, geosynthetic clay liners, compacted clay liners, or a combination of these as the hydraulic barrier or barrier. (EPA, 2002)

As shown in Figure 4-1, the proposed hydraulic barrier will be constructed of a composite of geosynthetic clay (GCL) and a 40-mil polyvinylchloride (PVC) liner. Placed under the PVC, the GCL liner serves both as the soil portion of the composite liner and as a cushion for the PVC liner. PVC liner is commonly used in the construction of cover systems, due to its ease



ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

**MULTI-LAYERED
COVER SYSTEM**

FIGURE

4-1

of installation and repair. The 40-mil thickness exceeds EPA's requirement of 30 mils (0.75 millimeter) for hazardous materials containment covers receiving timely cover (Koerner, 1998). This composite liner will minimize infiltration on the site.

4.1.2 Drainage Layer

As shown in Figure 4-1, the proposed drainage layer will be constructed of a composite geonet material and will be part of the cover system wherever a liner is included. The site will be graded so that both the drainage layer and the liner will slope at approximately three percent towards storm water drain inlets to ensure that water collected above the low hydraulic conductivity layers will not pool to any significant depth. The geonet composite will also act as a cushion layer between the PVC liner and cover soil layer.

The proposed composite geonet is functionally equivalent to the recommended drainage layer composed of a minimum of 12-inches of sand with a minimum hydraulic conductivity of 10^{-2} centimeters-per-second (cm/sec) (EPA, 1991). As shown in Table 4-1, performance of the two drainage systems was compared using the Hydrologic Evaluation of Landfill Performance (HELP) Model (EPA, 1994). Results of this analysis suggest that when used with a geonet drain layer, a one percent slope will provide equivalent protection from seepage infiltration as a three percent slope using a soil drainage layer composed of 12-inches of drainage material with a hydraulic conductivity of 1×10^{-2} cm/sec (EPA, 1991). HELP model runs for this evaluation are included in Appendix C.

TABLE 4-1. COMPARISON OF DRAIN LAYER MATERIAL AND SLOPE

Drainage Layer Design	Water from Drainage Layer (inches)	Depth of Water on Liner (inches)
12" Sand Drain Layer $k = 10^{-2}$ cm/sec, slope = 3%	0.86	0.18
Geonet Drain Layer $T = 6.35$ cm ² /sec, slope = 3%	0.85	0.00
Geonet Drain Layer $T = 6.35$ cm ² /sec, slope = 1%	0.84	0.00

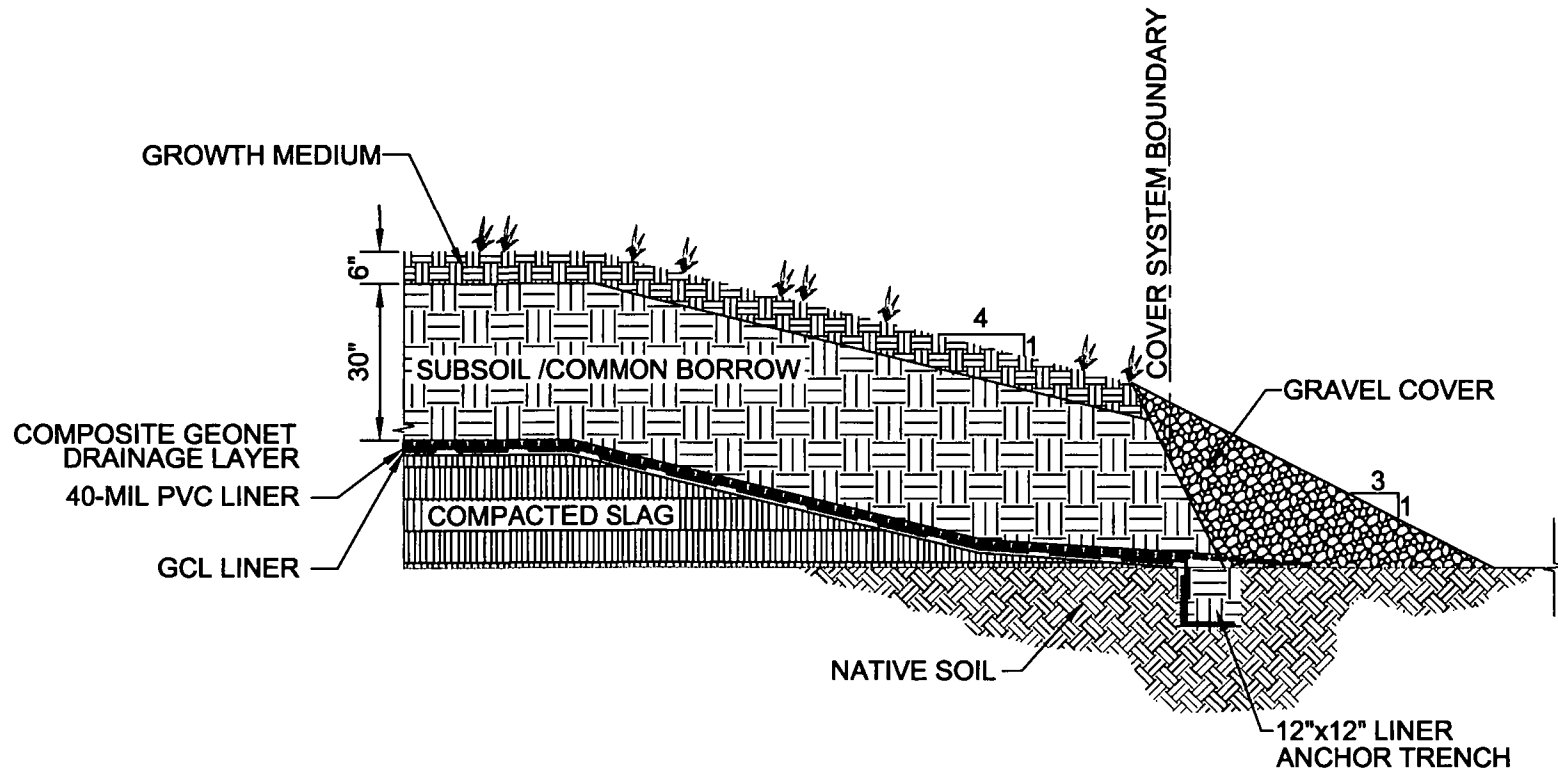
This drainage layer will prevent surface water from infiltrating and coming in contact with contaminated soils and slag and will promote drainage off the liner portion of the cover system.

4.1.3 Protective Layer

As shown in Figure 4-1, erosion protection is provided by a six-inch layer of growth medium for establishing a plant cover of grass. On the portion of the site to receive a liner as part of the cover system, the six-inch layer of growth medium combined with the 30-inch layer of cover soil provides 36-inches of total protection, as in the cover for the CAMU cells.

4.1.4 Anchor System

Around the perimeter of the cover system, the various components of the cover system will terminate and must be protected from erosion and damage. In most areas, the termination will be in soil where construction of an anchor trench with a gravel cover is possible. As shown in Figure 4-2, a typical anchor trench is one foot wide and one foot deep. Once the edges of the liners are placed in the trench, covering at least one side and the bottom of the trench, the trench will be backfilled with a compacted soil and bentonite mix that will securely anchor the liners in place and prevent drainage from the geonet from saturating the trench. As shown in Figure 4-3, in areas of the site where the cover system terminates on pavement, such as at the storm water inlet, stainless steel batten strips will be used to anchor the edges of the two liners to the pavement. The edges of the geonet will be covered with well-draining gravel that will resist erosion while allowing the geonet to freely drain along the edges of the cover system. As shown in Figure 4-4, in areas of the site where the cover system terminates at the slag pile, the typical one foot wide by one foot deep anchor trench will be used. Figure 4-5 shows a typical detail for termination of the multi-layered cover system along Upper and Lower Lakes. Figure 4-6 shows a typical detail for anchoring the multi-layered cover system where it shares a boundary with the soil removal area.

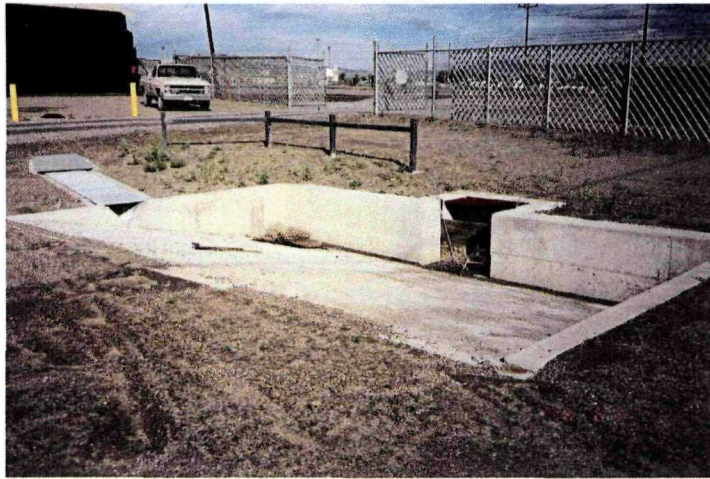


ASARCO EAST HELENA SMELTER
 COVER SYSTEM DESIGN

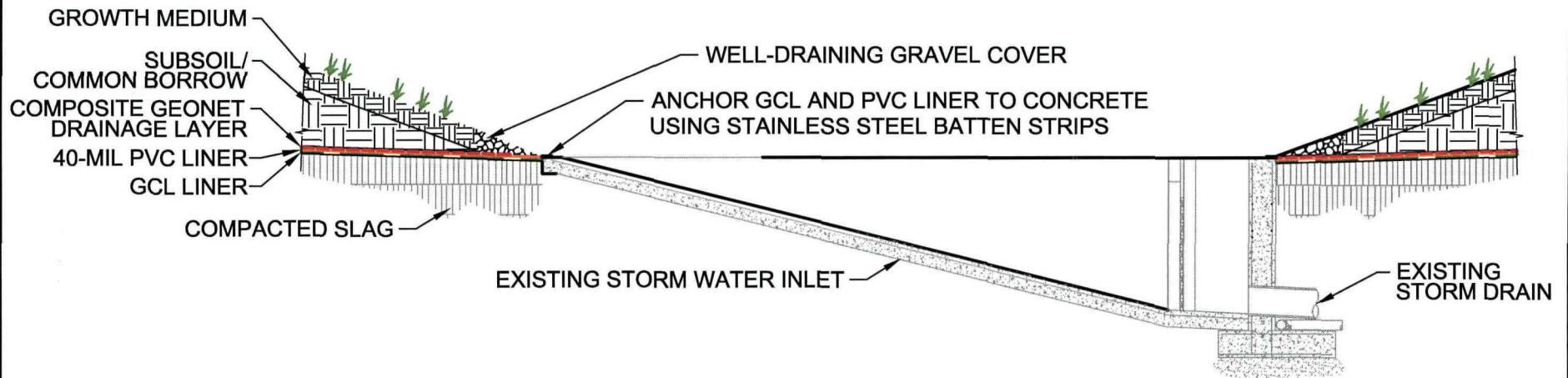
TYPICAL
 ANCHOR TRENCH

FIGURE

4-2



EXISTING STORM WATER INLET

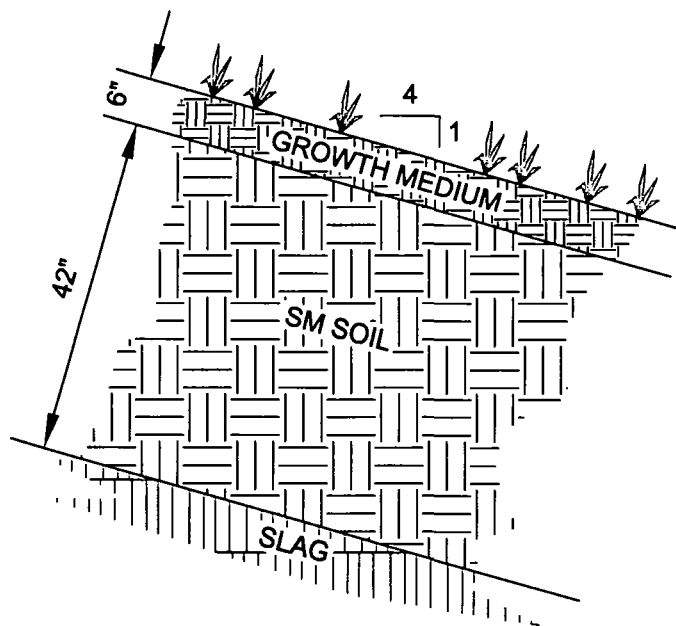


ASARCO EAST HELENA SMELTER
 COVER SYSTEM DESIGN

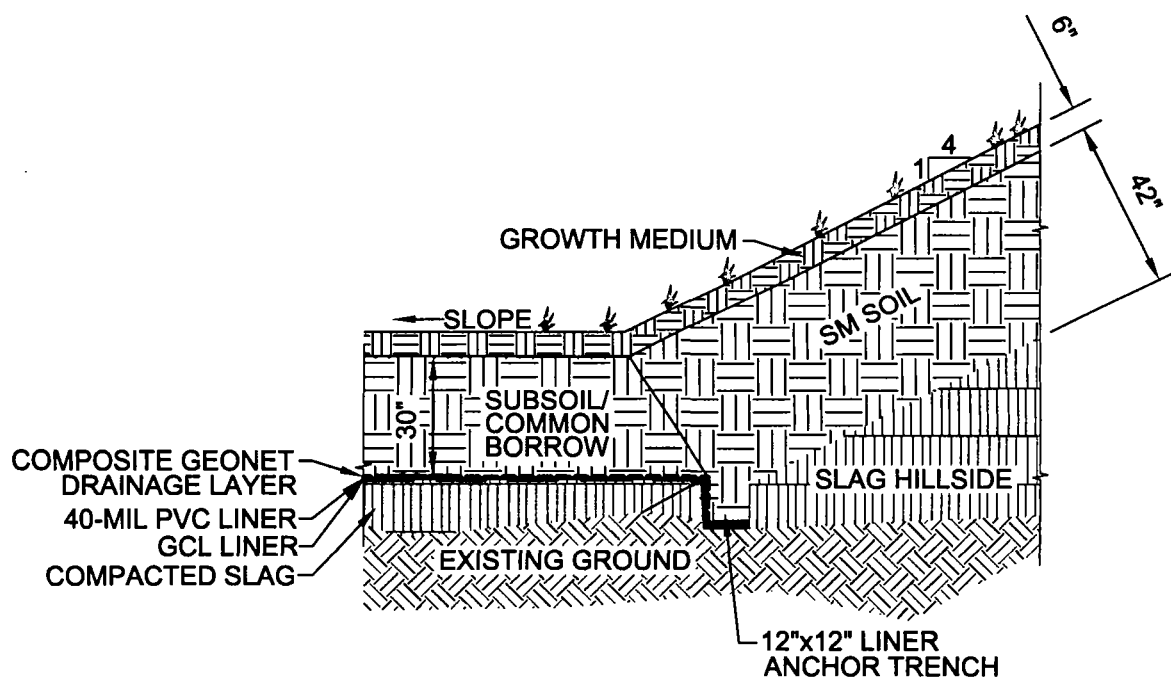
COVER SYSTEM TIE-IN TO EXISTING
 STORM WATER INLET DETAIL

FIGURE

4-3



TYPICAL SLAG PILE SOIL E.T. COVER SECTION



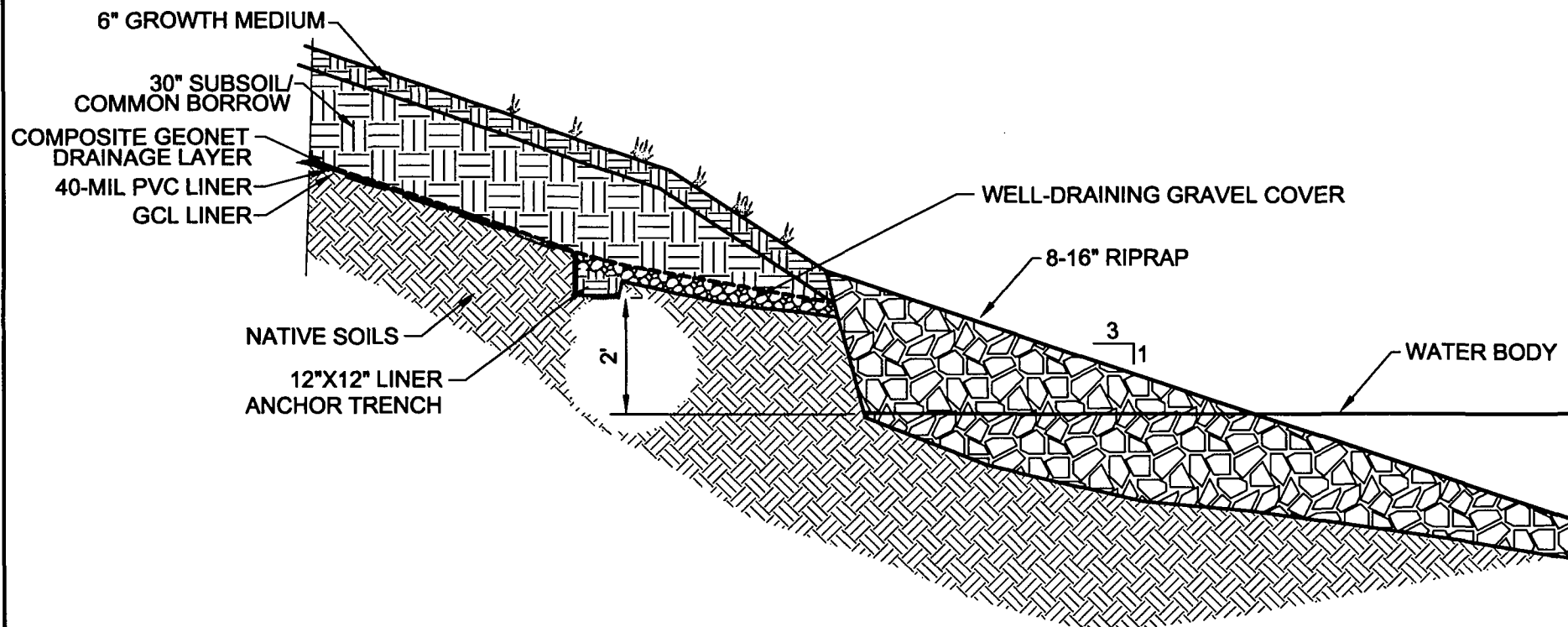
TYPICAL COVER TRANSITION AT TOE OF SLAG PILE

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COVER SYSTEM DESIGN

SLAG PILE
COVER SYSTEM

FIGURE

4-4



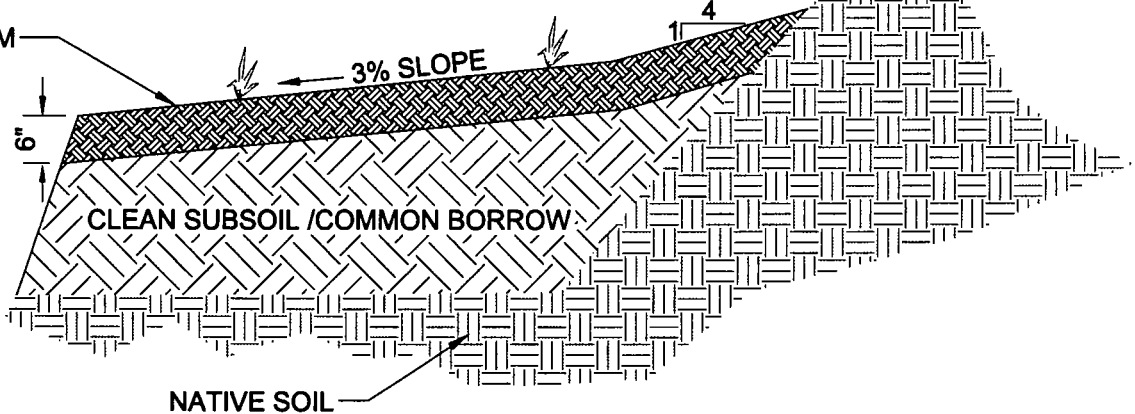
ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

COVER SYSTEM TERMINATION
AT UPPER AND LOWER LAKE

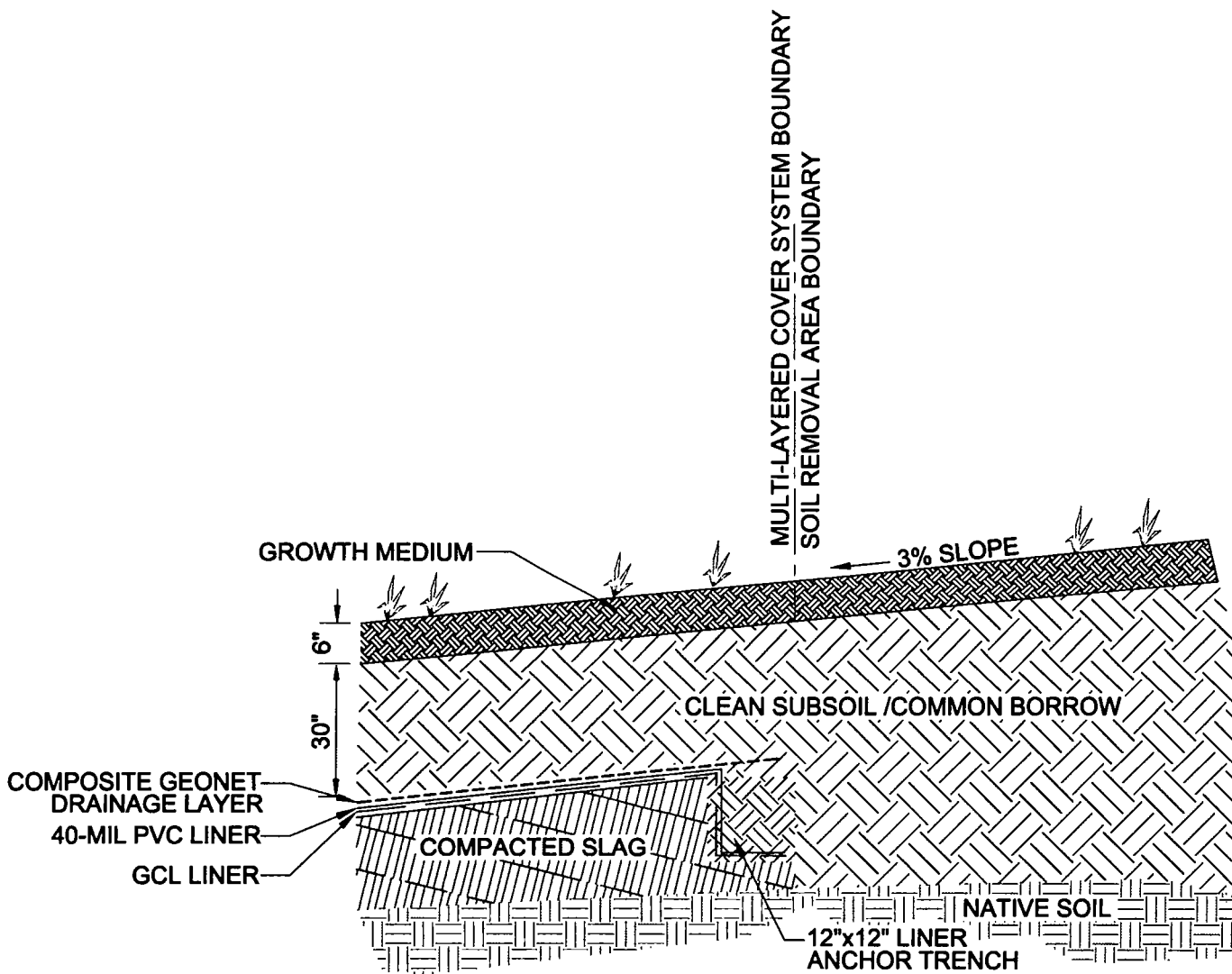
FIGURE

4-5

GROWTH MEDIUM



TYPICAL CAP BOUNDARY OF SOIL REMOVAL AREA



BOUNDARY OF SOIL REMOVAL AREA AND MULTI-LAYERED CAP

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

SOIL REMOVAL AREA
COVER SYSTEM DETAILS

FIGURE

4-6

4.2 EVAPOTRANSPIRATION COVER FOR SLAG PILE

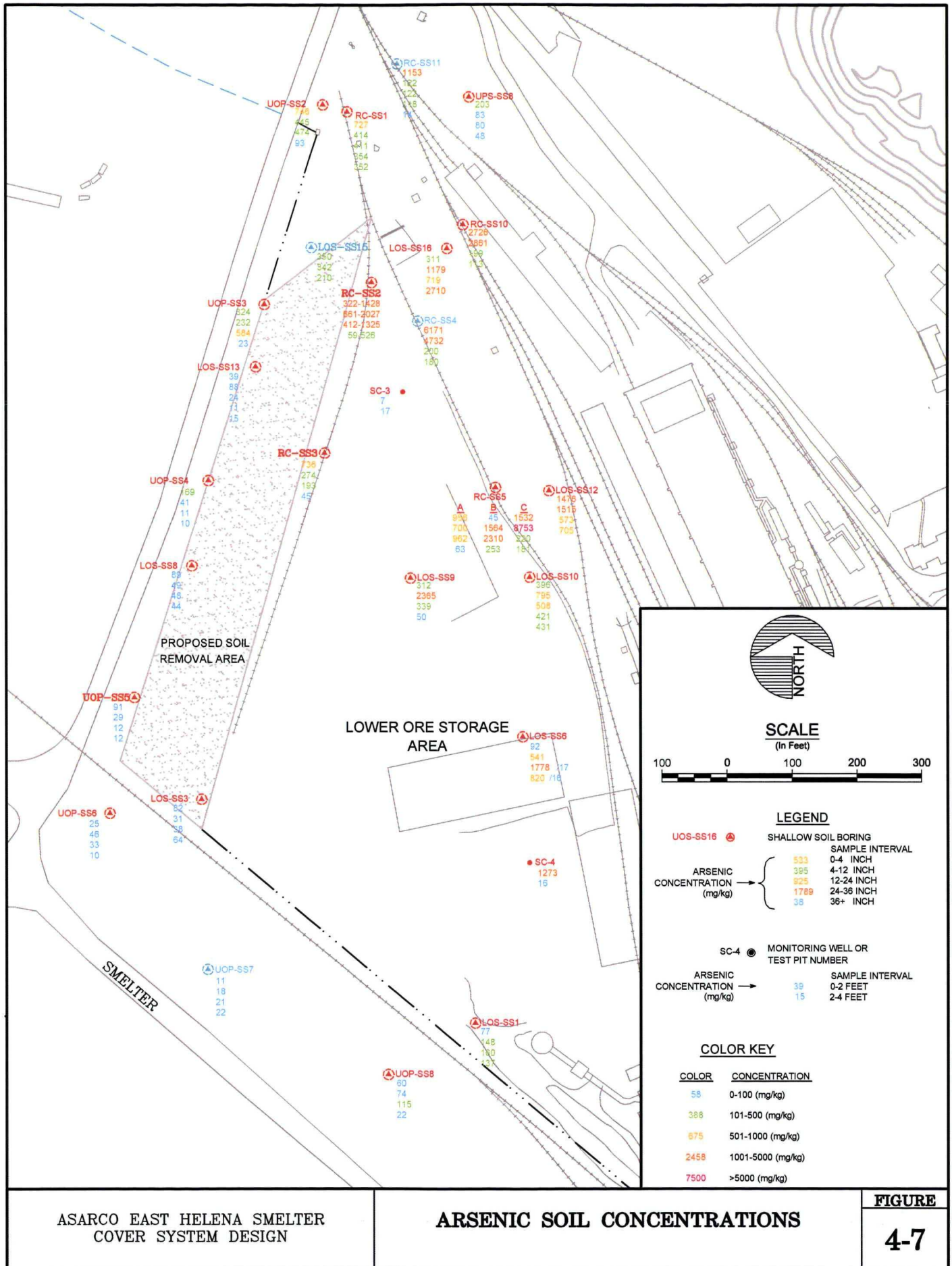
Although the RI/FS concluded that the potential for impacts to groundwater and surface water from slag is low, recent groundwater data collected in fall 2007 suggest a source of elevated selenium concentrations in groundwater beneath the slag pile. To minimize the potential for infiltration of water, the slag pile will be covered with an evapotranspiration (ET) cover system consisting of 42-inches of engineered cover soil (SM soil) and 6-inches of growth medium (Figure 4-4).

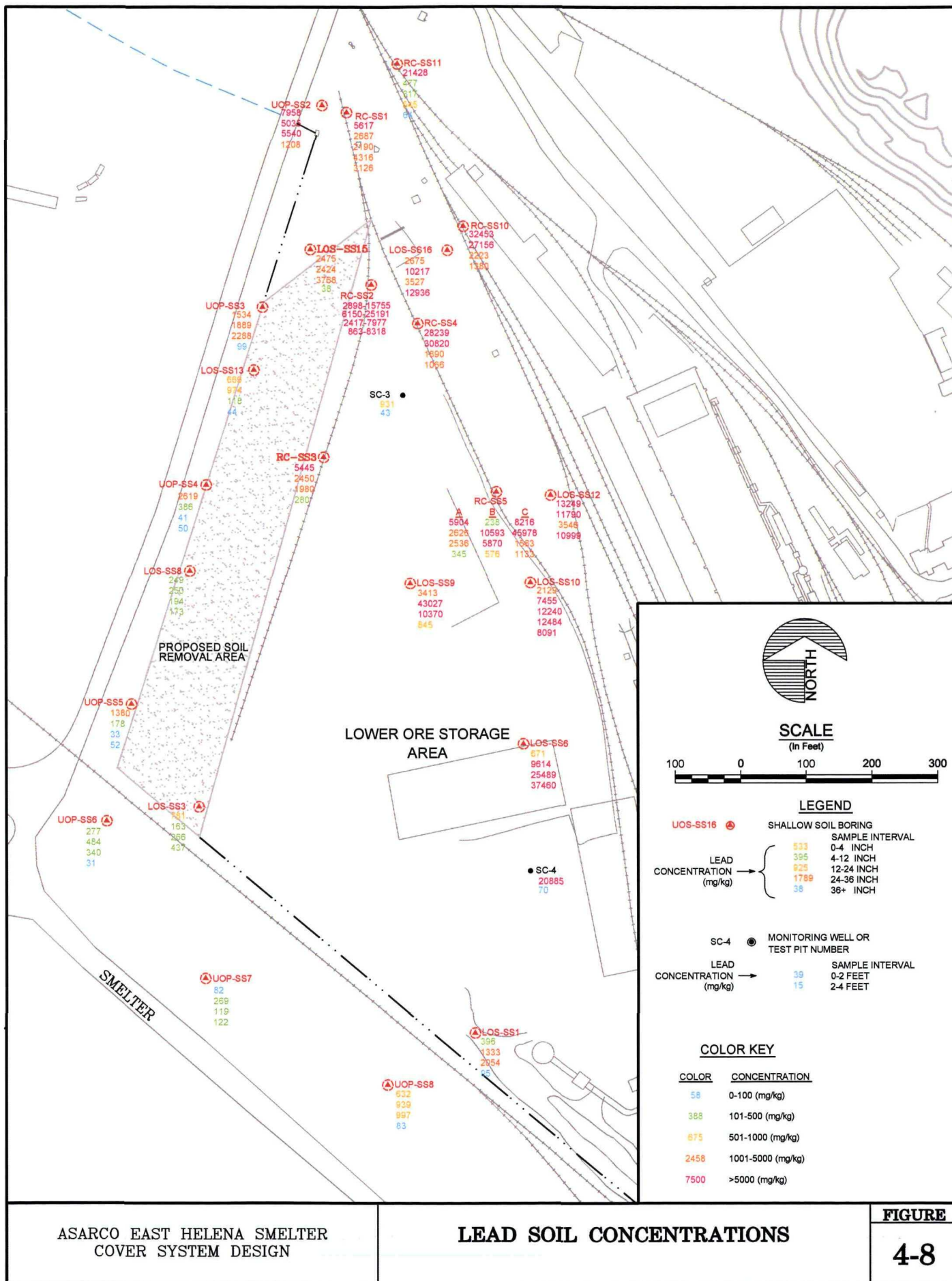
The cover soil will consist of sandy silt/clay loam material locally available from nearby Asarco property. The growth medium, also locally available from nearby Asarco property, will be capable of sustaining native plant growth and protecting the cover soil layer from frost effects and rooting damage. The growth medium will be seeded with a mixture of native vegetation designed to provide a variety of rooting depths to facilitate the transpiration of moisture from the cover.

Using conservative estimates of the storage capacity of the soil from the NRCS Soil Survey, precipitation data from the wettest year on record, and evapotranspiration data from the AGRIMET station located in the Helena Valley, calculations show a cover system thickness of 48-inches is adequate to prevent significant infiltration. Preliminary calculations are shown in Appendix D.

4.3 SOIL REMOVAL AREA

As shown in Figure 4-6, the proposed cover system for this area includes 6 inches of growth medium and vegetation to prevent erosion of the soil. Figures 4-7 and 4-8 show the surface concentrations of arsenic and lead respectively in the northwest corner of the site where grading will result in excavation of two or more feet of surface soil in order to get the cover system to drain towards the storm water inlet. The excavated soils removed from this area will be integrated as fill material under the multi-layered cover system. The proposed excavation will remove surface soil in this area. Based on existing site data (see Figures 4-7 and 4-8), average soil arsenic and lead concentrations following soil removal will be





28 mg/kg and 143 mg/kg, respectively. This would be significantly lower than EPA's cleanup goals for undeveloped lands for commercial/industrial use of 270 mg/kg for arsenic and 1300 mg/kg for lead. The proposed excavation will similarly reduce other metals concentrations in the remaining soils.

4.4 MONITORING WELL EXTENSIONS

All monitoring wells that will be covered with the final cover system will need to be extended, as shown in Figure 4-9.

5.0 STORM WATER SYSTEM

Management of storm water to minimize infiltration and erosion on site is integral to the proposed cover system for the East Helena Plant. The existing site will be covered with an engineered fill of slag and soil that will be encapsulated by the cover system. The surface of the fill will be generally graded with a slope towards the north end of the site to promote drainage of the cover system to two existing major storm water inlets located there. The proposed cover system includes storm water management structures to provide for efficient removal of runoff from the capped site and to allow for initial monitoring of storm water quality data for the site. For the short term, existing storm water treatment will remain in place to address water quality concerns for discharges to public surface waters. However, if as expected, the storm water from the covered site meets discharge standards without treatment, the existing water treatment system is expected to be removed at some time in the future.

5.1 PROPOSED STORM WATER MANAGEMENT SYSTEM

Storm water receptors, such as storm drain inlets and conveyances, will need to handle runoff from the 25-year 24-hour design storm. Asarco will utilize the existing storm water management system, described in the East Helena Plant Storm Water Pollution Prevention Plan (ASARCO, 2006) and the Spill Prevention Control and Countermeasure Plan (ASARCO, 2007), to collect the majority of the storm water runoff from the capped area. An analysis was conducted to determine if changes to the existing storm water management system would be needed once the proposed cover system is in place.

5.2 STORM WATER HYDROLOGY

Drainage structures for the covered site were designed for runoff resulting from the 25-year, 24-hour rainfall event, which has a four percent chance of occurrence in any given year. Rainfall losses in the form of infiltration were estimated using the United States Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS) curve number method.

5.2.1 Precipitation

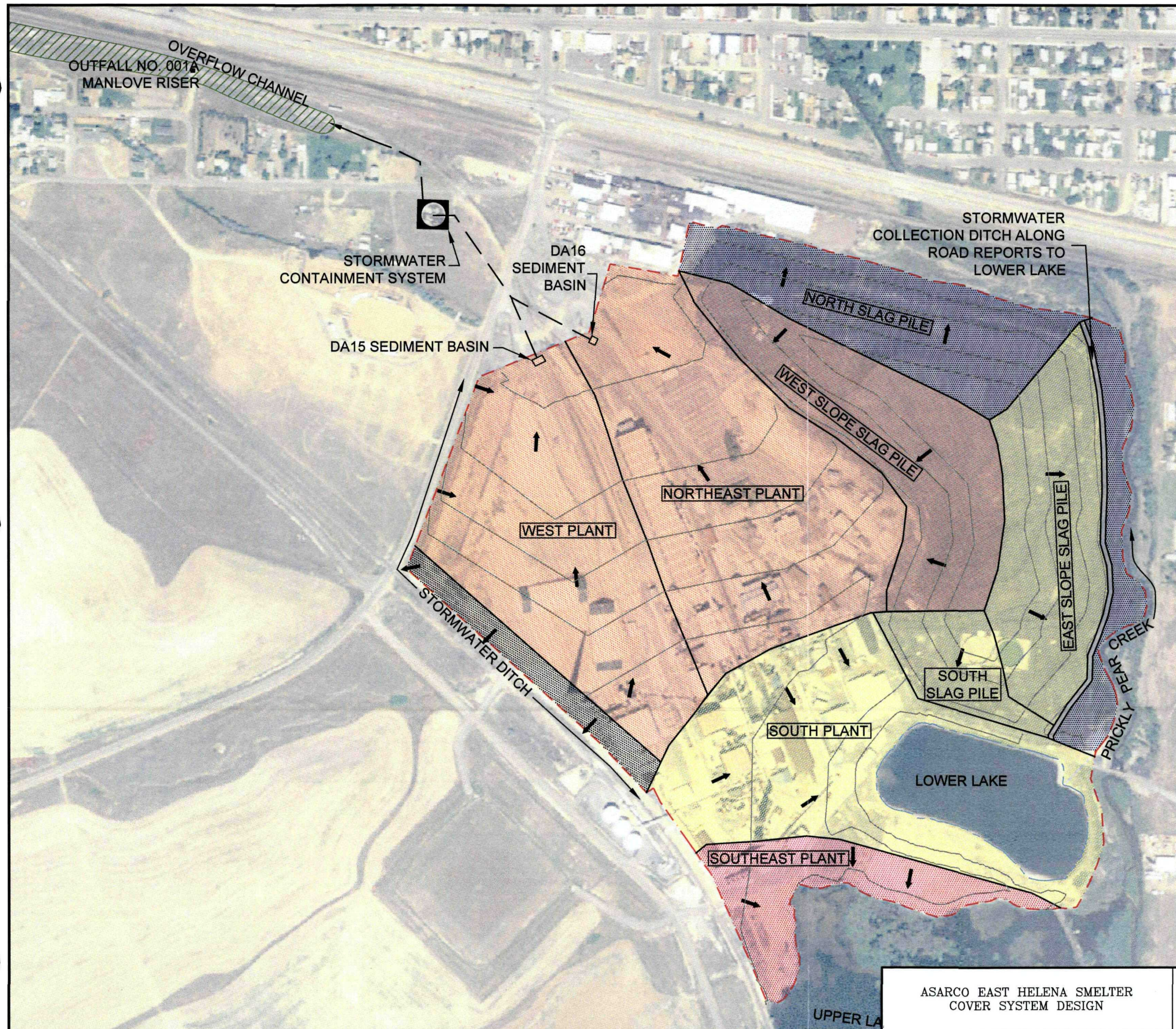
Total rainfall depth for the 25-year, 24-hour storm event was obtained from National Oceanic and Atmospheric Administration (NOAA, 1973) Atlas 2, published by the National Weather Service. Based on the isopluvial contour lines on Figure 28 of NOAA Atlas 2, total precipitation depth for the design storm is 2.3 inches. Temporal distribution of the incremental rainfall depths was determined using the NRCS Type I distribution curve. Using six-minute time increments, a maximum intensity of 0.17 inches per six-minute increment was calculated, which is approximately 0.03 inches-per-minute.

5.2.2 Drainage Areas

Proposed grading of the site is shown on Figure 5-1, Site Storm Water Plan, which includes arrows to show the direction of surface runoff flow. Basins were identified according to receiving water body and subbasins were delineated based upon drainage flow direction and coverage system design. A multi-layered cover system, which includes three-feet of cover soil, is proposed for most of the plant area, while a four-foot thick vegetated evapotranspiration cover is proposed for the slag pile. Both propose to use soil imported from fields south of the plant site.

As shown in Figure 5-1, approximately 47 percent of the covered site will be graded to allow surface runoff to flow to the northwest and into two existing sediment basins, DA15 and DA16, which are located on the west side of the facility. Sediment basin DA15 discharges to a 27-inch diameter concrete drain pipe and sediment basin DA16 discharges to an 18-inch diameter concrete pipe. Both pipes eventually join at a manhole and combine discharge to a 30-inch diameter pipe that flows to a storm water retention tank northwest of the plant site.

Approximately 36 percent of the site will be graded to drain into Lower Lake, including a diversion along the east side of the slag pile. With an area of over six acres, Lower Lake provides a significant amount of storm water capacity and detention time. The remainder of the site storm water will run off into either Prickly Pear Creek, as in the case of the north side



SCALE
(In Feet)
0 400

LEGEND

- RUNOFF TO STORMWATER COLLECTION SYSTEM
- RUNOFF TO PRICKLY PEAR CREEK
- RUNOFF TO DITCHES
- RUNOFF TO UPPER LAKE
- RUNOFF TO LOWER LAKE
- SLOPE DART - SHOWS DIRECTION OF RUNOFF
- DEPRESSION STORAGE AREA
- SOUTH PLANT
- STORM WATER BASIN

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

SITE STORM WATER PLAN

FIGURE
5-1

of the slag pile, into Upper Lake, or into roadside ditches around the site perimeter. The north side of the slag pile accounts for another 23 percent of the runoff area, while the drainage area into Upper Lake accounts for approximately six percent. Drainage to roadside ditches will occur from a small strip of cover system along the perimeter of the cover and accounts for the remaining one percent of area. The total area of the cover is approximately 118 acres.

5.2.3 Runoff Losses

Losses associated with infiltration were based on the NRCS curve number (CN) method. CN is determined by soil type and the condition of vegetation. The highest possible CN is 98, representing a ground surface that is totally impermeable and all rainfall will become runoff. The NRCS Soil Survey reports that sandy loam from the field south of the plant, which is proposed as a borrow source for the cover system, is a Hydrologic Class B soil. The existing CAMU, which has a good grass cover, was used to judge the quality of vegetation that will be established once the site cover system is completed. A CN of 61, which corresponds to rangeland and grassland in class B soil and with good vegetation, was used for the proposed cover system that will include one to three feet of cover soil imported from fields south of the plant.

5.2.4 Time of Concentration

Time of concentration, T_c , which determines the shape of the runoff hydrograph from each subbasin, was determined by the Kirpich equation in the StormNET[®] model, which is

$$T_c = (0.01947(L^{0.77})(S^{-0.385}))$$

where: T_c = Time of Concentration (min)
L = Flow length (ft) and
S = Slope (ft/ft).

Each subbasin properties for average slope and flow length were entered into the model.

A summary of the site hydrologic characteristics for the basin discharging to outfall 001A is shown in Table 5-1.

TABLE 5-1. SITE HYDROLOGIC CHARACTERISTICS

Subbasin (Figure 5-1)	Drainage Area (acres)	Average Slope (%)	SCS Curve Number	Time of Concentration (min)
West Plant	23.2	3	61	7.1
Northeast Plant	20.2	3	61	7.6
West Slope Slag Pile	12.4	25	61	2.9
Total	55.8			

5.3 STORM WATER RUNOFF ANALYSIS RESULTS

Runoff from the capped areas of the site was modeled using StormNET[®], a surface water hydrology and routing computer model. Using the design rainfall event (25-year, 24-hour storm), the model estimates surface runoff hydrographs from site subbasins and routes flows through conveyance channels or pipes to a receiving water or containment facility. From the storm water analysis results, that are found in Table 5-2, it appears that the existing storm water structures are adequate for the design runoff from the cover system and that runoff into the two monitored storm water discharge points, Outfall 001A and Lower Lake, account for 83 percent of the runoff.

**TABLE 5-2. STORM WATER RUNOFF QUANTITIES
AND RECEIVING WATERS**

Basin	Area (Acres)	25-Yr Volume (Acre-Feet)	Percent Total (%)	Receiving Waters
West Plant	23.2	0.77	19.3	Outfall #001A
Northeast Plant	20.2	0.66	16.7	Outfall #001A
West Slope Slag Pile	12.4	0.44	11.2	Outfall #001A
Subtotal	55.8	1.87	47.2	Outfall #001A
East & South Slag Pile	20.3	0.72	18.1	Lower Lake
South Plant	22.2	0.71	17.9	Lower Lake
Subtotal	42.5	1.43	36.0	Lower Lake
North Slag Pile	12.1	0.42	10.6	Prickly Pear Creek
Southeast Plant	6.7	.22	5.5	Upper Lake
Site Perimeter	1.2	0.04	1.0	Roadway Ditches
Total	118.3	3.97	100.0	

Of primary concern, and the primary focus of the storm water runoff analysis, is the ability of the existing storm water facilities in the northwest corner of the site to adequately discharge and store runoff from the area. The estimated discharge from the site was routed through existing storm water pipes and eventually to the existing containment facility. Appropriate size and roughness information was entered into the model to reasonably estimate the peak flows and discharge volumes for each component of the system. As summarized in Table 5-3, the analysis concluded that the existing facilities are adequate to handle the runoff from at least a 25-year storm event on the site.

**TABLE 5-3. SUMMARY OF RUNOFF RESULTS AT
EXISTING FACILITY COMPONENTS**

Existing Storm Water Component	Pipe Capacity (cfs)	Peak Discharge (cfs)	Peak Discharge to Pipe Capacity Ratio
Sediment Basin DA15 (27-inch)	17.9	0.82	0.05
Sediment Basin DA16 (18-inch)	3.45	1.23	0.36
Junction of DA15 and DA16	60.9	2.0	0.03
	Storage Capacity (acre-feet)	Runoff Volume (acre-feet)	Runoff Volume to Storage Ratio
Storm Water Containment Facility	3.9*	3.0	0.77

*Includes Steel Tank + Concrete Secondary Containment. Does not include the surrounding depression, which adds an additional 5.2 acre-feet of storage (See Figure 5-1).

5.4 SURFACE RUNOFF MONITORING

Surface runoff water quality will be monitored for a period of time using existing storm water monitoring practices to determine effectiveness of the site cover. Therefore, until the site is fully covered, storm water entering the retention basin will be handled in the same manner as it is currently. Runoff will be temporarily held in the containment facility prior to being pumped back to the water treatment plant, treated and discharged to Lower Lake. The water treatment plant is expected to be one of the last structures to be demolished and will remain operable until the site cover system is substantially complete. Never the less, storm water from the retention basin will be tested before discharge to public waters for a period of time

following closure of the water treatment plant in order to ensure that the cover system has adequately addressed water quality concerns. Similarly, discharge from Lower Lake will continue to be monitored as it is currently until the data suggests that water quality concerns have been adequately addressed.

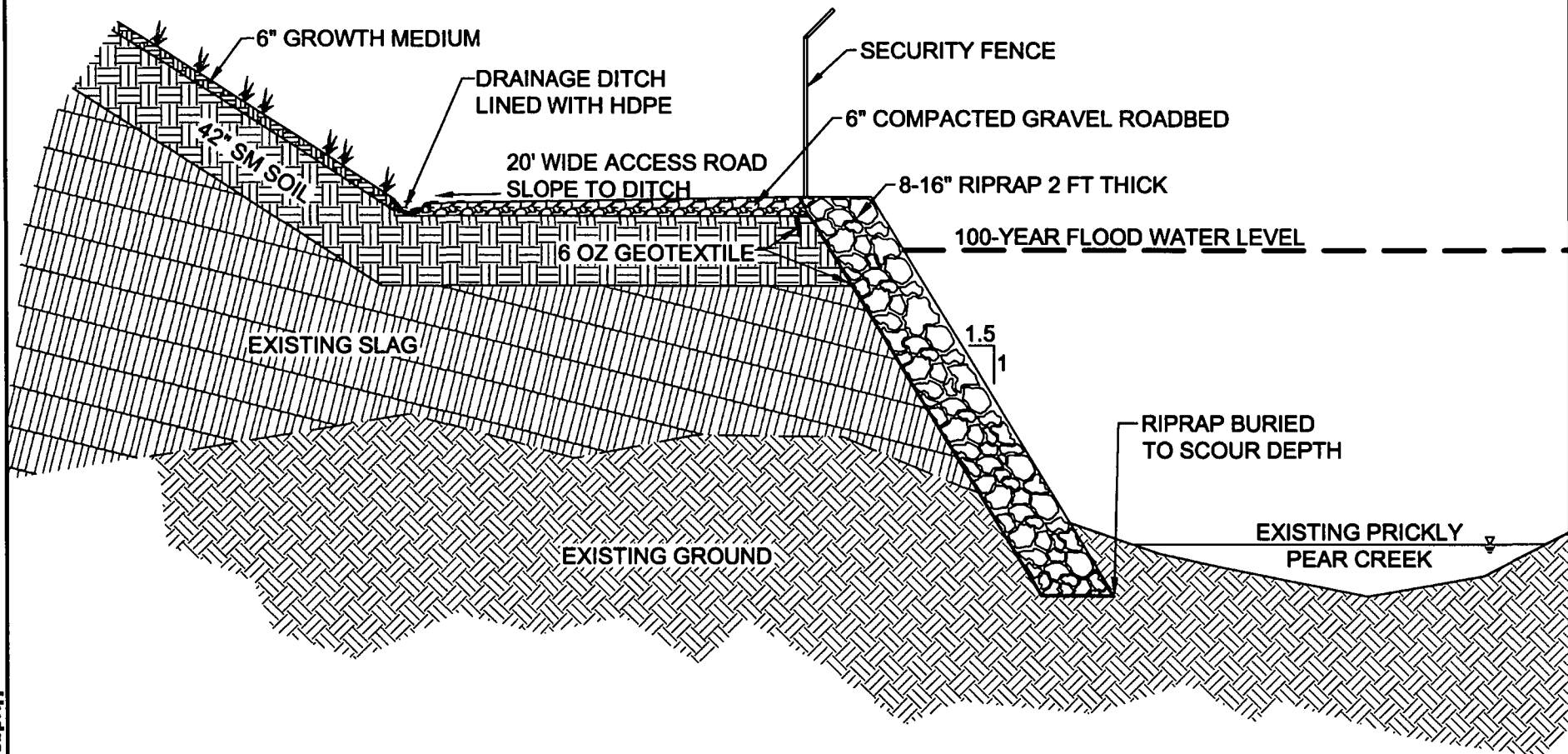
6.0 STREAMBANK PROTECTION

The final cover system on the slag pile is adjacent to Prickly Pear Creek and in several locations it will intersect the stream bank. Riprap armor is proposed along the east side of the slag pile as part of the final cover system in order to prevent erosion of slag from up to the 100-year flow event in Prickly Pear Creek. Discharge and water surface elevations for the 100-year flow in Prickly Pear Creek were taken from the HEC-2 flood model for the City of East Helena Flood Insurance Study (FEMA, 1985).

Riprap armor was appropriately sized for flow velocities from the 100-year Prickly Pear Creek flow of 2,190 cubic feet per second (cfs). Information from the Federal Emergency Management Agency (FEMA) Flood Insurance Studies for Lewis and Clark County and the City of East Helena were input into the HEC-RAS, River Analysis System (USACOE, 2005), hydraulic model to determine flow velocities and bank full elevations from the 100-year flow event. Channel flow velocities in Prickly Pear Creek in this area during the 100-year flow event range from 5.24 feet per second (fps) to 7.48 fps. Therefore, the riprap design for this cover system used a flow velocity of 8 fps.

Riprap armor was sized in accordance with the California Bank and Shore Protection Design Manual (CALTRANS, 2000) and the U.S. Army Corps of Engineers Hydraulic Design of Flood Control Channels Design Guide (USACOE, 1995). Calculations for riprap design, which are included in Appendix E, resulted in specification of a two-foot thick layer of 16-inch (maximum) riprap with a specific gravity of 2.65 or greater. Specifications for the riprap are included in Appendix A. As shown in Figure 6-1, the design includes a maximum slope of 1.5:1 for the armored bank of Prickly Pear Creek and a layer of geotextile filter fabric under the riprap.

Table 6-1 is a summary of the proposed riprap armoring design.



ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

TYPICAL
ROADWAY AND RIPRAP DETAIL

FIGURE

6-1

**TABLE 6-1. DESIGN SUMMARY OF PROPOSED RIPRAP
ARMORING ALONG PRICKLY PEAR CREEK**

Prickly Pear Creek Station (from City of East Helena FIS)	100-Year Water Surface Elevation (NGVD)	Elevation of Top of Riprap (NGVD)	Elevation of Bottom of Riprap (NGVD)
N	3903.79	3905.79	3898.7
M	3896.36	3898.36	3889.5
L	3890.31	3892.31	3883.2

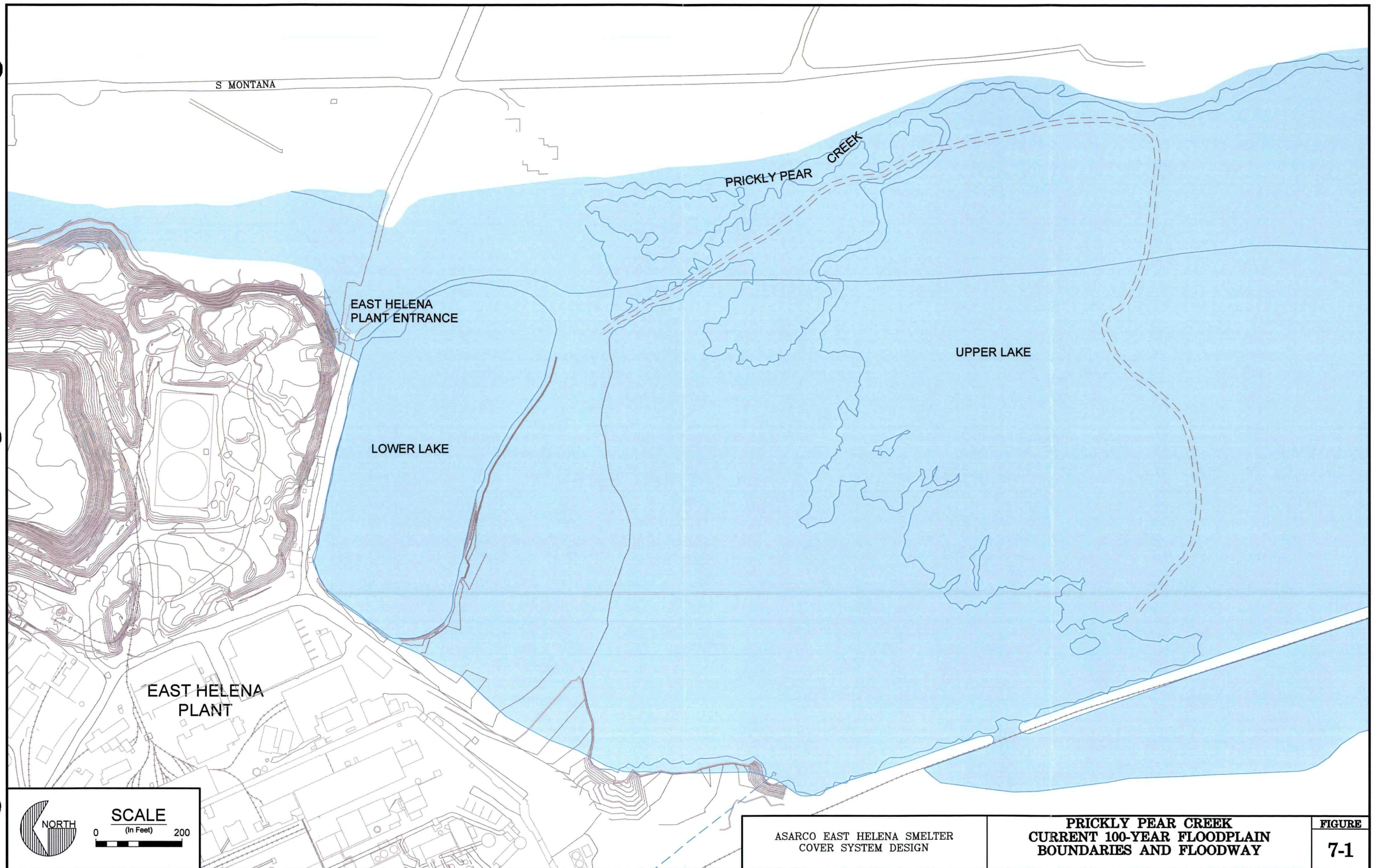
7.0 FLOODPLAIN PROTECTION

Hydrometrics conducted a flood analysis of Prickly Pear Creek for the purpose of analyzing impacts to the site cover system and evaluating options for mitigating flood impacts. Prickly Pear Creek flows generally in a northerly direction along the east side of the smelter property. Existing floodplain boundaries for the 100-year flood for Prickly Pear Creek, which is defined as a flood having a one percent probability of exceedance in any given year, are published in the Flood Insurance Rate Maps (FIRMs) for the Flood Insurance Studies (FISs) for the City of East Helena (FEMA, 1985) and Lewis & Clark County (FEMA, 2002). The current floodplain boundaries in the area of Asarco's East Helena Plant, shown as blue shading on Figure 7-1, encompass all of Upper and Lower Lake.

The objectives of this analysis, which is contained in Appendix F, included:

1. Characterize the current impacts to the East Helena Plant from a 100-year flood on Prickly Pear Creek, using updated topographic data in the area of Lower Lake.
2. Evaluate the feasibility of constructing a dike or placing fill to prevent Prickly Pear Creek from flooding the East Helena Plant area, and evaluate impacts to the Prickly Pear Creek floodplain from construction of the dike or fill.
3. Evaluate impacts to Prickly Pear Creek floodplain and the East Helena Plant resulting from removal of all or a portion of the dam that is generally referred to as the Smelter Dam, located at the east entrance to the plant.

Analysis of the impact of a 100-year flood concluded that there are a number of options for preventing Prickly Pear Creek from flooding the East Helena Plant site. However, there are regulatory limitations to building a protective dike because it would be within the designated floodway and privately owned. Removing the entire east-entrance dam structure also presents problems with implementation because of significant stream regrading and reconstruction.



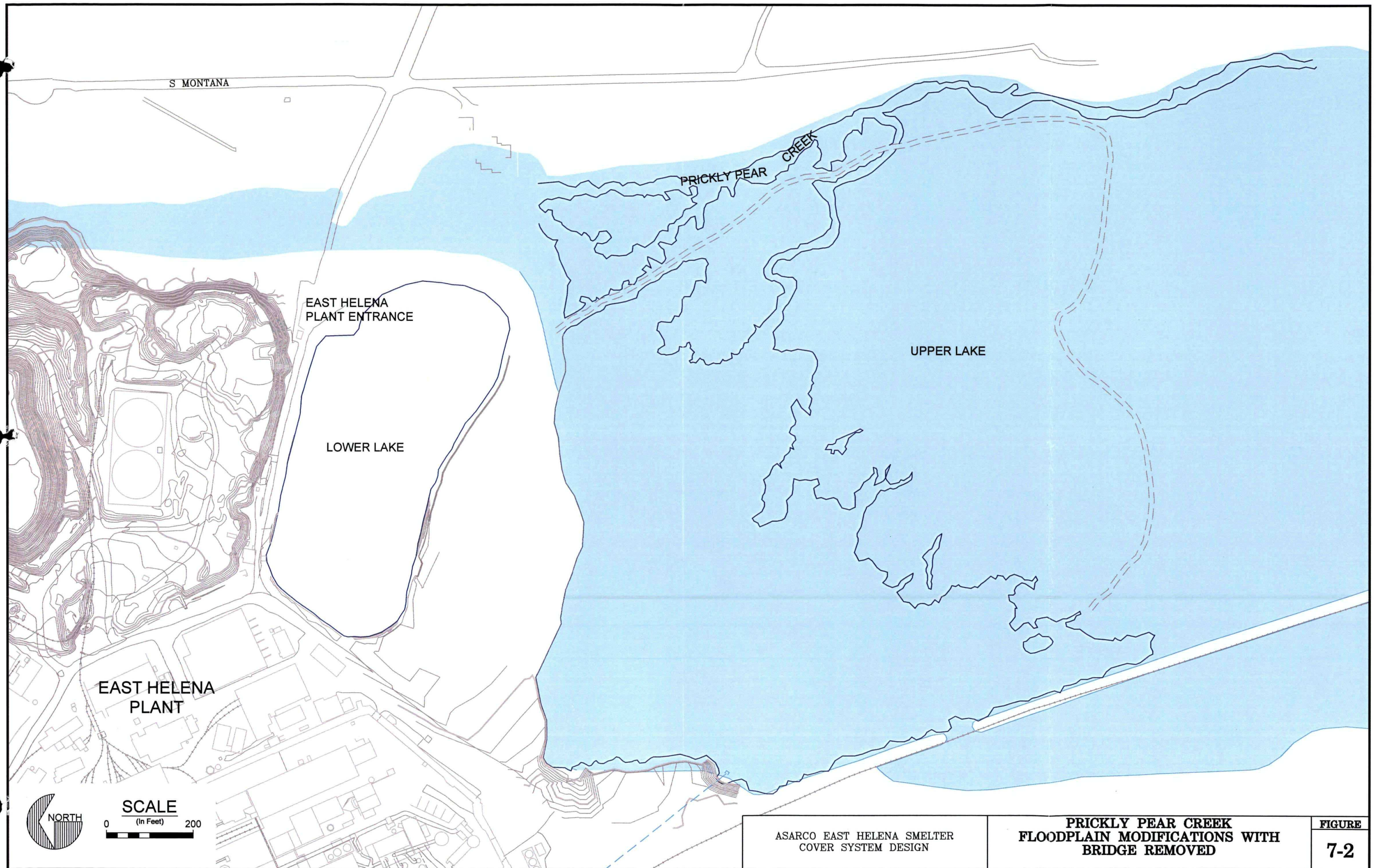
ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

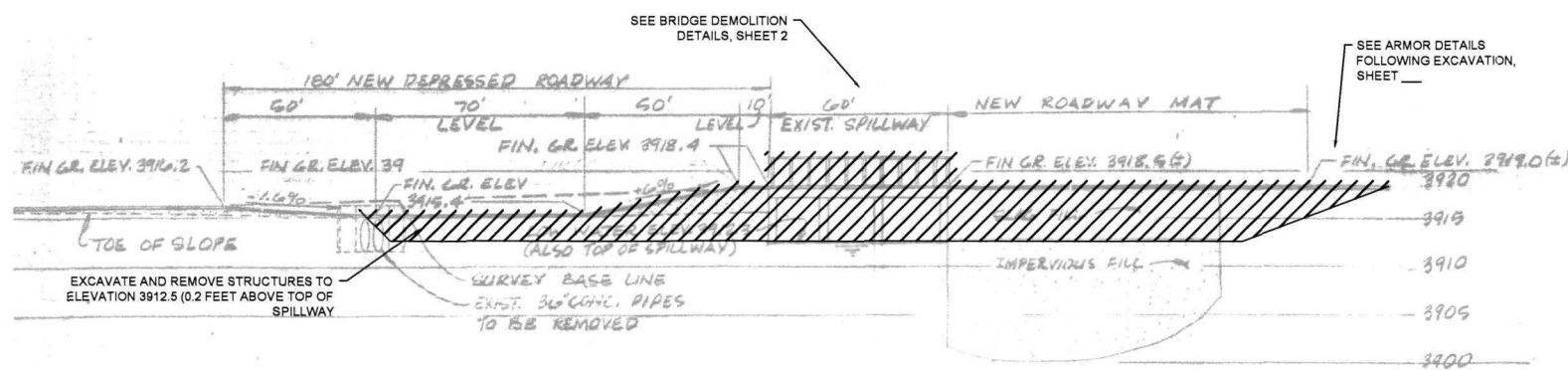
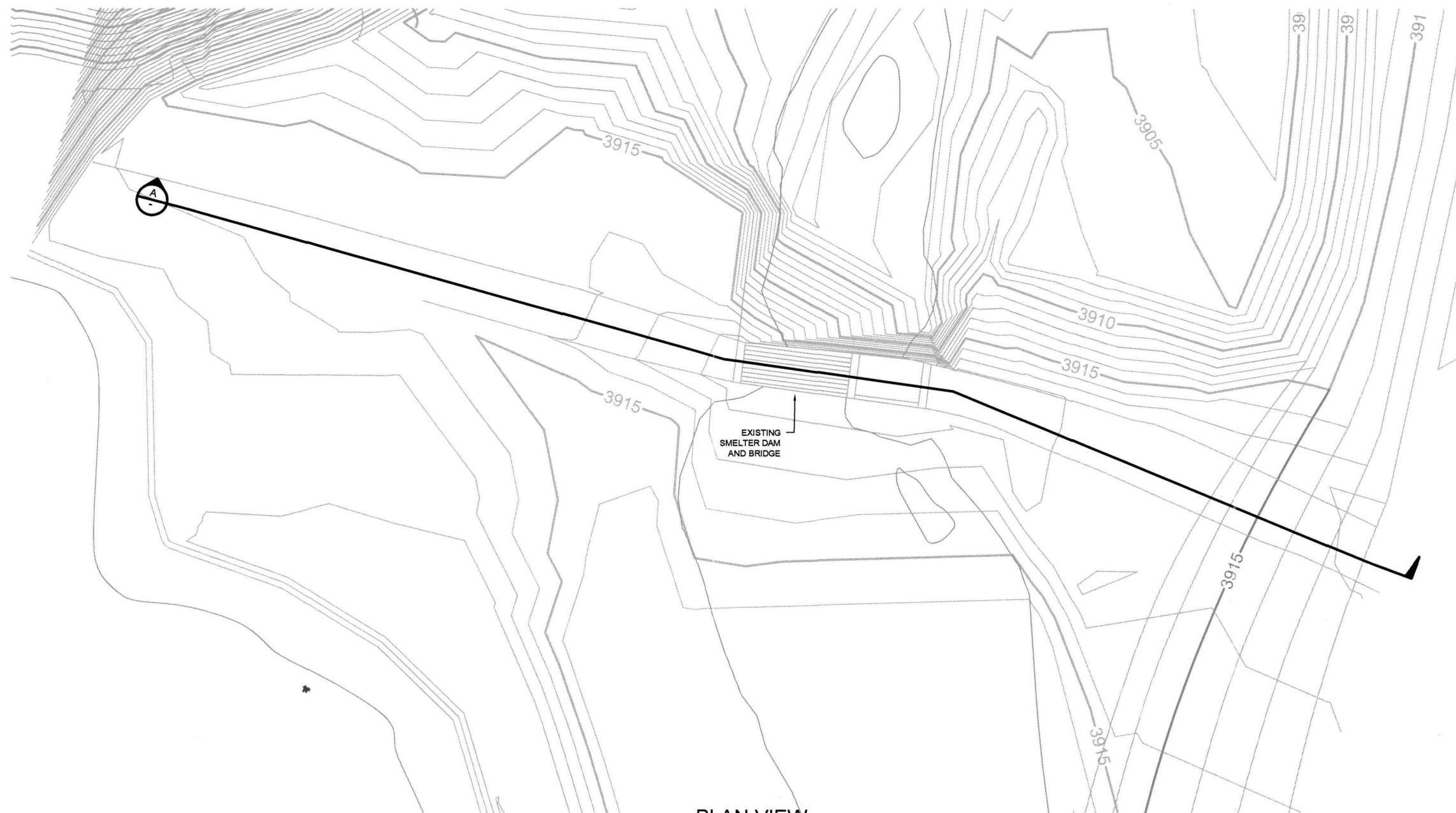
**PRICKLY PEAR CREEK
CURRENT 100-YEAR FLOODPLAIN
BOUNDARIES AND FLOODWAY**

FIGURE

7-1

At this time, removal of the east entrance bridge structure and abutment ramps appears to be the best alternative. This alternative would not require removal of the bottom portion of the dam, which would remain in place. Therefore, it will maintain the stream grade at its current elevation. However, as shown in Figure 7-2, removal of the bridge will lower the 100-year flood water surface elevations upstream of the dam and adjacent to Lower Lake sufficiently to protect the site and cover system. Removal of the bridge will not affect downstream 100-year flood elevations (See Appendix F). At a location approximately 600 feet upstream of the dam near the northern end of Upper Lake, removal of the bridge will lower the 100-year flood water surface elevation by only about 0.3 feet. However, at the location of the bridge, its removal will lower the 100-year water surface elevation approximately 2.9 feet. The most significant disadvantage to bridge removal is that it will eliminate the east entrance to the plant, but this may actually benefit site security of the plant. Figures 7-3 and 7-4 show the portions of the bridge structure that will be removed.





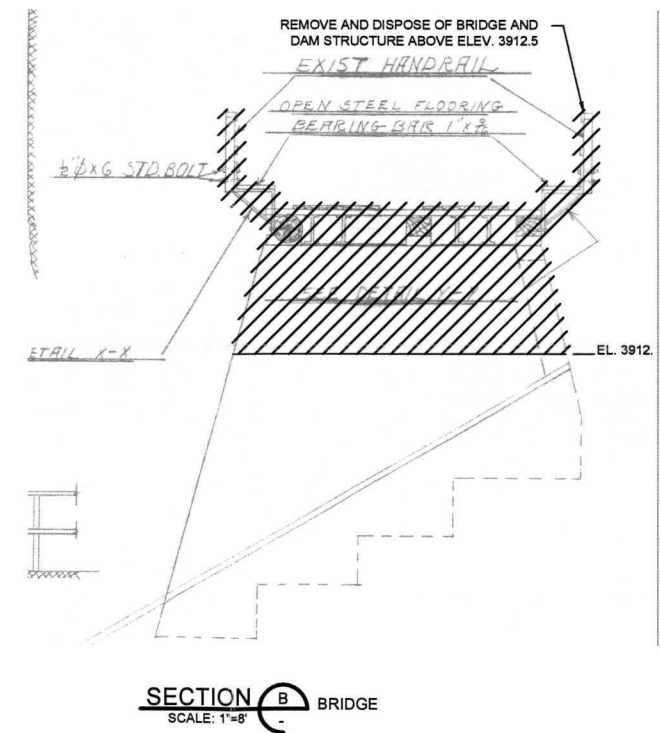
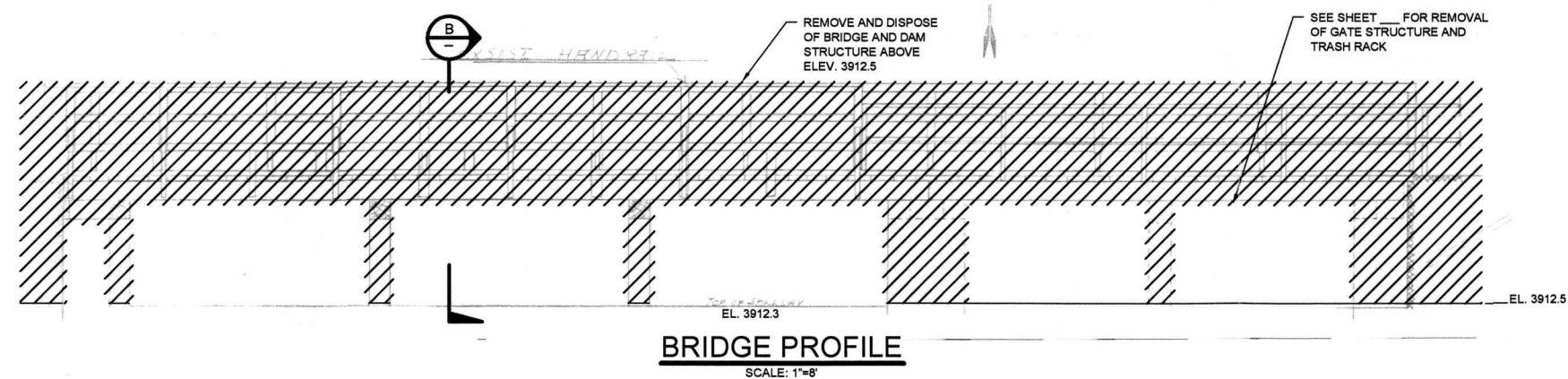
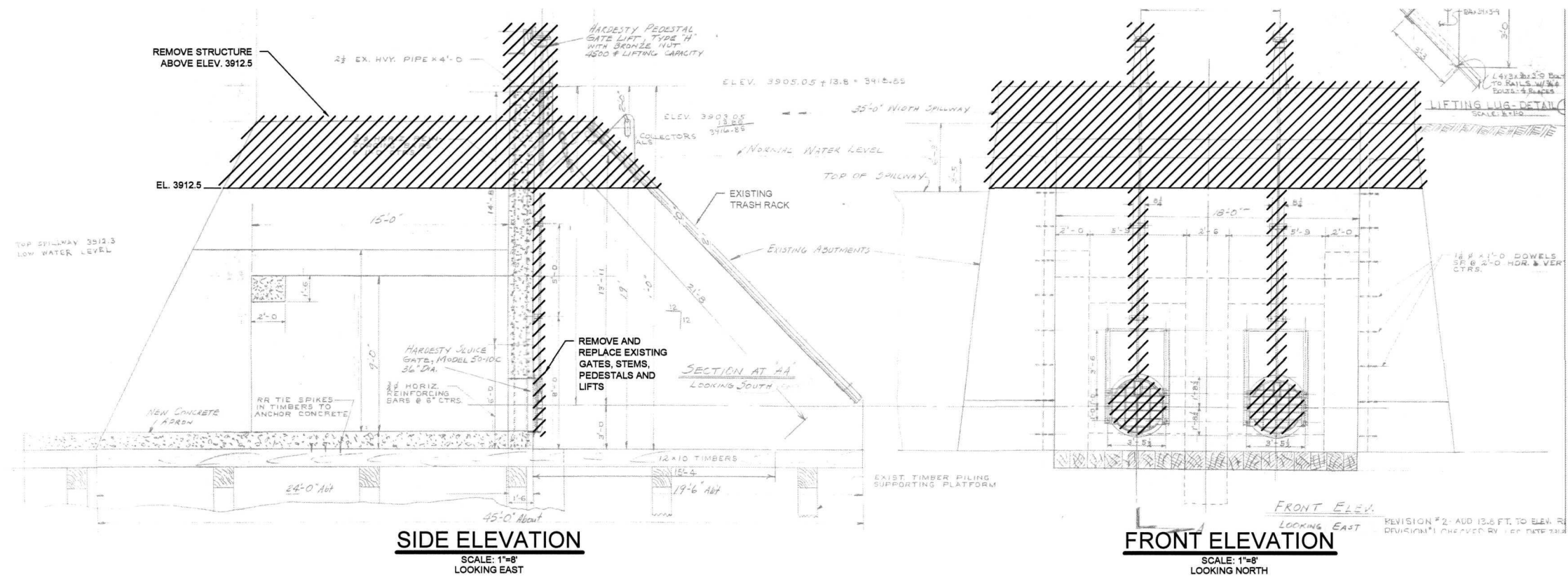
NOTE:
EXISTING CONDITIONS DEPICTED ARE AS SHOWN OF DRAWING
ASARCO 1-7087 (1981). ACTUAL EXISTING CONDITIONS MAY HAVE
CHANGED.

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

PLAN VIEW OF BRIDGE STRUCTURE
TO BE REMOVED

FIGURE

7-3



ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

SECTION VIEW OF BRIDGE STRUCTURE
TO BE REMOVED

FIGURE

7-4

8.0 SECURITY AND MAINTENANCE

Longevity of the cover system is an integral part of the protection of both human health and the environment. Therefore, it is critical that the cover system be protected from both human and animal interaction. Since a phased approach will be taken to installing the final cover system, temporary security and maintenance procedures will be implemented. Temporary and long-term site security and maintenance will ensure that the integrity of the cover system is not jeopardized.

8.1 TEMPORARY SITE SECURITY AND MAINTENANCE

The Asarco East Helena Smelter facility will be fenced with a 6-foot high woven wire farm fence installed in accordance with Montana Department of Transportation specification 712.02 until completion of the cover system or until it is replaced with permanent fencing. A single strand of barbed wire will be strung 3-inches above the top of the woven wire for added security. Gates (24 feet wide) will be provided at the access roads. Temporary orange poly fence (safety fence) will be installed along the interior edges of the final cover system to eliminate the potential for disturbance to the cover system between construction seasons.

Cover system liner will be exposed between construction seasons along the interior perimeter of the final cover system, as explained in Section 9, and will require routine inspection and maintenance. Temporary on-site maintenance items are to include repairs to the exposed liner, seams, and sandbags. Exposed cover liner integrity and anchorage are the primary focus of scheduled inspection and preventative maintenance. Periodic inspection of other features, such as above-ground portions of monitoring wells and storm water controls, will also be required.

8.1.1 Housekeeping

Liner Anchorage – Sandbags that are used to anchor the membrane liner may need periodic adjustment to ensure they maintain proper spacing.

8.1.2 Routine Inspection and Maintenance

Problems may be encountered during the construction of the cover system or prior to permanent closure of the site. Several problems that may be encountered during routine inspection include subsidence, rips and tears of liners, liner seam separation, and liner anchorage.

1. Subsidence - When an area experiences excessive localized settlement, the cover may no longer drain properly. Even so, there may not be a problem unless the area is large, there is continued ponding, or the cover system liner has been damaged.

If it is determined that a repair must be made, the necessary steps involved are:

- a. Determine limits of area to be repaired.
- b. Remove cover soil from area.
- c. Cut and remove cover system liners.
- d. Fill depression and grade for proper drainage.
- e. Install and seam new cover system liners.
- f. Test seams to ensure integrity of repair.
- g. Replace cover soil and revegetate.

2. Rips and tears - Repair of rips and tears in the liner is necessary not only to prevent water from leaking through but also to prevent wind from getting under the liner. If allowed to get under the liner, high winds may inflate the surface of the cover system. Inspection for rips and tears should be conducted prior to cover soil placement and along edges of the cover system with exposed liner. If it is determined that a repair must be made, the cover system liner should be repaired by appropriate methods.

3. Seam separation – Repair of separating or inadequately sealed seams is necessary for the same reasons as repair of rips and tears in the liner. Seams can be temporarily repaired using seaming tape, but should be permanently repaired by appropriate methods as soon as a liner installer can be called to the site.

4. Liner anchorage – High winds may cause liner edges to pull out or temporary sandbags or sand tubes to displace along edges of the cover system with exposed liner. If this occurs, anchor trenches will be excavated, liner edges reinstalled, and the trench filled and compacted in accordance with the liner installation plans. Sandbags or sand tubes will be repositioned to provide evenly spaced anchorage on the cover system liner.

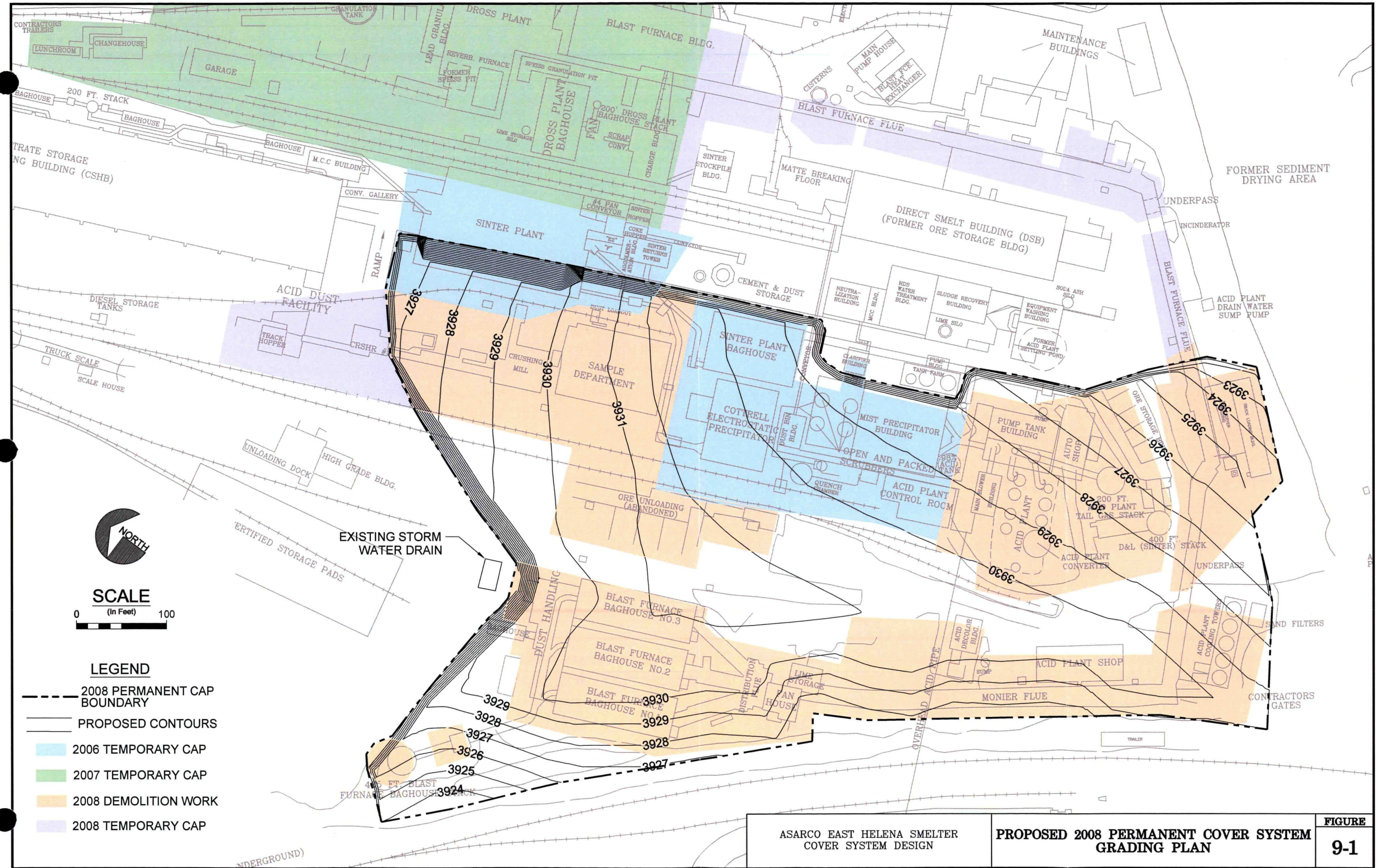
8.2 LONG-TERM SITE SECURITY AND MAINTENANCE

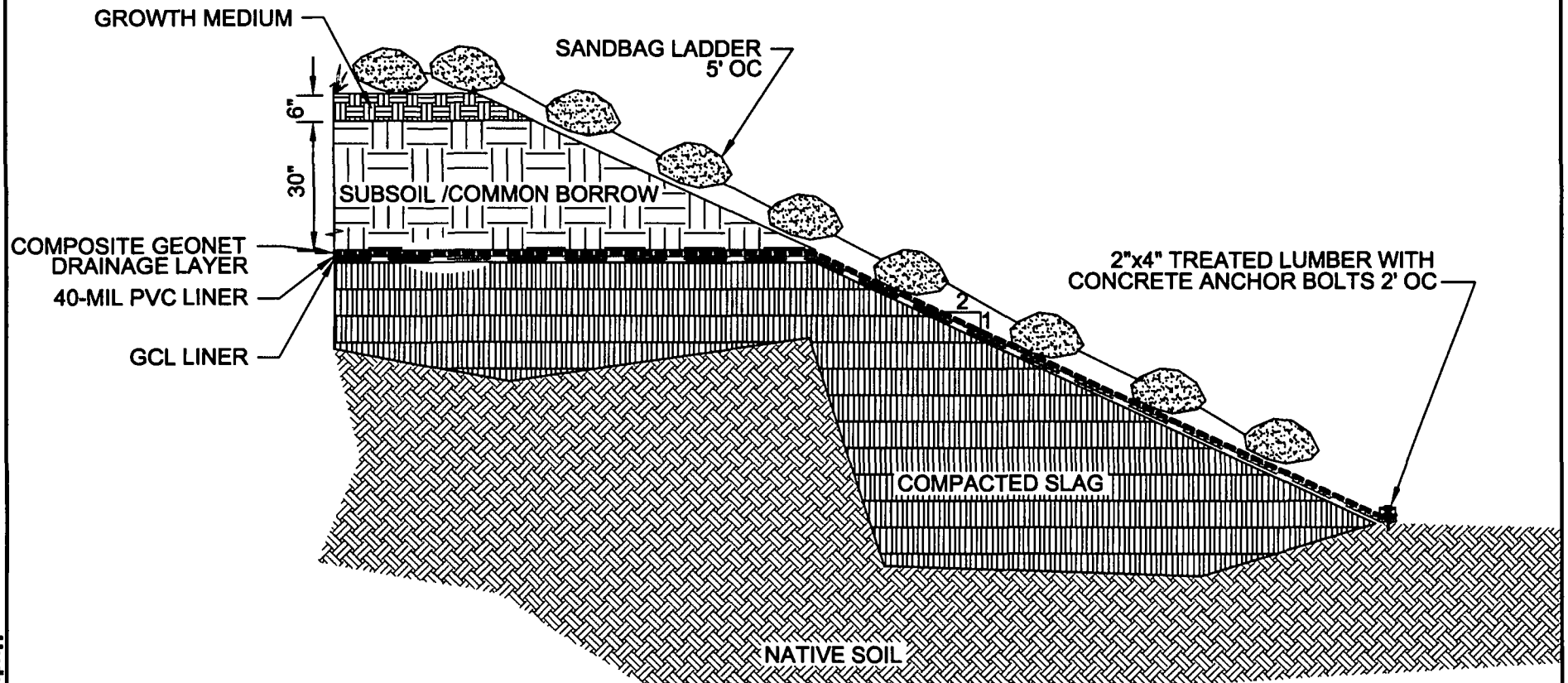
Permanent site security fencing will be installed as sections of the cover system are completed along the site boundary. An 8-foot high chain link fence with a 3-strand barbed wire top section will be used for permanent site security fencing. Gates (20-24 feet wide) will be provided at the access roads.

Long-term maintenance will be conducted, as part of a post-closure monitoring plan, which will be not be presented at this time. The post-closure monitoring plan, to be submitted after completion of the cover system, will include information on the long-term monitoring of the cover system integrity including subsidence and surface erosion.

9.0 2008 COVER SYSTEM CONSTRUCTION

Asarco will prepare the 2008 Cleaning and Demolition Project Work Plan for submittal no later than March 15, 2008. Once approval is received from the Montana Department of Environmental Quality (MDEQ), Asarco plans to proceed with the cleaning and demolition work set forth in the Work Plan. The 2008 schedule for cleaning and demolition will coincide with the availability of the CAMU Phase 2 to accept wastes generated under this Work Plan. Asarco proposes to proceed with construction of the proposed cover system to the extent practical once cleaning and demolition is completed, eliminating the need for placement of a less protective temporary cap in some areas. Figure 9-1 shows the area of the site for which Asarco proposes to complete cleaning, demolition, grading, and cover system construction during calendar year 2008. The proposed construction includes permanently anchoring the cover system along the perimeter of the site. However, interior edges of the cover system would remain temporarily anchored to the existing pavement or surface with batten boards and sandbags. Figure 9-2 shows a typical detail for how the grading and cover system would temporarily be terminated along interior edges. Asarco anticipates that the permanent cover system will require less maintenance and repair and be more protective of the site than if temporary caps are used.





ASARCO EAST HELENA SMELTER
 COVER SYSTEM DESIGN

TEMPORARY COVER
 SYSTEM TERMINATION

FIGURE

9-2

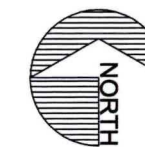
10.0 IMPLEMENTATION OF THE EAST HELENA SUPPLEMENTAL ENVIRONMENTAL PROJECT

Design and construction activities that are necessary to implement the SEP will be conducted in three phases. Phase 1 addresses work associated with implementation of a flow short circuit system between Upper Lake and Lower Lake to minimize the flow through the fill between these water bodies. Phase 2 of the work addresses those work items associated with the wetlands and riparian areas that make up the shoreline of Lower and Upper Lakes. Phase 3 includes those work items associated with the four-acre upland area positioned between the two lakes.

As part of general construction planning, submission and approval of a Five Year Noxious Weed Management Program is necessary to comply with State of Montana County Noxious Weed Control Act (Title 7, Chapter 22, Sections 7-22-2101 through 7-22-2153) MCA and Rules 4.5.201 through 4.5.204 for activities proposed in this SEP. A SEP Weed Management Plan will be developed for Lewis and Clark County Weed District approval prior to the implementation of Phase 1.

10.1 PHASE 1

Three gated pipe conveyances between Upper and Lower Lake will be constructed to channel controlled flows of water from Upper Lake to Lower Lake (Figure 10-1). These constructed flow corridors will short circuit flow through the fill between the lakes. The result will be a preferred pathway between the ponds, a leveling of water levels between Upper and Lower Lake, and a minimization of groundwater flux through the fill between the ponds. The combination of reduced groundwater flux between the ponds and direct flow connection between Upper and Lower Lakes will result in improved water quality in Lower Lake that should ultimately meet 1989 Process Pond ROD (EPA, 1989) standards for Lower Lake (Table 10-1). Improvements in water quality and level controls will also augment efforts for further vegetation and wildlife habitat enhancements.



SCALE
0 (In Feet) 120

LEGEND

- SHORELINE FILL (TO BE REVEGETATED)
- TOPSOIL AND GRASS
- WETLAND AND RIPARIAN VEGETATION
- TREES AND SHRUBS

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

RIPARIAN AREA ENHANCEMENTS

FIGURE

10-1

TABLE 10-1. ROD STANDARDS FOR LOWER LAKE

Constituents	ROD Standard (mg/L)*
Arsenic	0.02
Cadmium	0.01
Copper	0.004-0.008
Lead	0.05
Zinc	0.11

**Environmental Protection Agency, 1989.*


Table 10-2 shows existing soil metal data, soil leachate data (SPLP) and water quality data from soil sample sites and monitoring wells completed in the areas between Lower Lake and Prickly Pear Creek. Although total metals in the fill are elevated in arsenic and metals, concentrations in groundwater are mildly elevated and relatively low. Comparison with SPLP concentrations and groundwater well water quality results show leachate and groundwater concentrations are similar, suggesting the contribution of arsenic and metals to groundwater in the fill is limited.

Table 10-3 shows results of adsorption testing conducted as part of the Phase I RFI contaminant modeling effort. This effort is described in detail in the Phase I RFI report (ACI, 2003). Part of this effort was to predict the impacts of unsaturated soils on groundwater. As Table 10-3 shows, the fill between Upper Lake and Lower Lake has a high capacity to adsorb arsenic, particularly, at higher concentrations. However the potential for soil leaching (negative soil adsorption values) is low. Only one test sample (OUS-SS18, SOL 8) showed a slightly negative value, indicating a slight leaching potential in water with low arsenic concentrations.

Infiltration model results are shown on Figure 10-2. As the figure shows, limited impacts were predicted for the fill between Upper and Lower Lake and predicted groundwater concentration from fill soils is less than 0.01 mg/l for arsenic. The predicted elevated concentrations at the west edge of the fill (0.1 ppm contour, orange area) are a result of

Table 10-2. Soil Leachate and Water Quality Data - Fill Area Between Upper and Lower Lake

Site/ Sample #	Sample Interval (ft)	Sample Date	Sample Time (hr/min/sec)	Analytical Parameters	As (ppm)	Cd (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)
UOS-SS11	12-24"	10/3/01	11:10	Total Metals SPLP	9256 2.000	451 0.410	4666 0.015	26492 0.140	7043 1.900
UOS-SS12	12-36"	10/3/01	9:40	Total Metals SPLP	214 0.012	71 0.007	542 <.004	2804 <.005	2478 0.032
UOS-SS18	0-4"	10/3/01	13:50	Total Metals SPLP	972 0.06	582 0.10	1939 0.0070	9676 0.0170	6578 0.0850
	24-36"	10/3/01	14:05	Total Metals SPLP	1815 0.044	728 0.670	4375 0.023	22680 0.260	14742 1.300
APSD-7		11/14/01		Dis Metals GW	6.7	0.2	0.009	0.02	0.5
APSD-8		11/14/01		Dis Metals GW	0.7	< 0.001	< 0.004	< 0.005	< 0.02
APSD-9		11/14/01		Dis Metals GW	0.9	0.005	0.007	0.008	0.2
APSD-10		11/14/01		Dis Metals GW	0.5	< 0.001	< 0.004	< 0.005	0.03
APSD-11		11/14/01		Dis Metals GW	0.2	< 0.001	< 0.004	< 0.005	0.03
APSD-12		11/14/01		Dis Metals GW	0.07	< 0.001	< 0.004	< 0.005	< 0.02

 Color indicates surface soil site and monitoring well proximity.

Source: Appendix 7, Phase I RFI Report, ACI 2003.

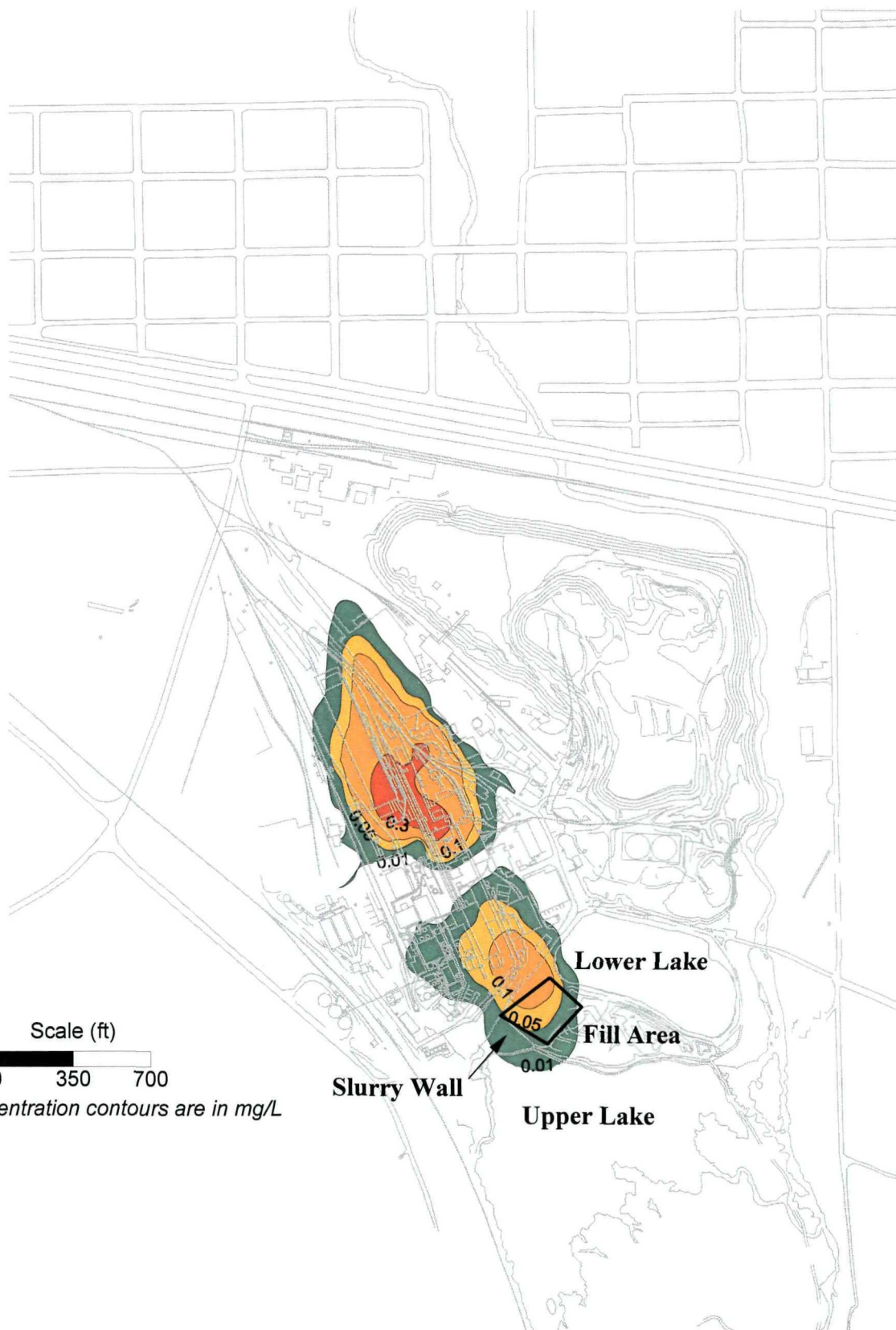
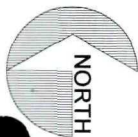
Table 10-3. Soil Adsorption Testing Data - Fill Area Between Upper and Lower Lake

Site/ Sample #	Sample Interval (ft)	Analytical Parameters	SOL 1 As (ppm)	SOL 2 As (ppm)	SOL 3 As (ppm)	SOL 4 As (ppm)	SOL 5 As (ppm)	SOL 6 As (ppm)	SOL 7 As (ppm)	SOL 8 As (ppm)
UOS-SS11	2-3'	Initial Concentration (mg/l)	186.5	95.5	48	24	9.65	4	1	0.12
		Final Concentration (mg/l)	83	30	6.4	0.98	0.21	0.086	0.057	0.048
		Adsorbed Concentration (ug/g)	1035	655	416.0	230.2	94.4	39.14	9.43	0.72
UOS-SS12	2-3'	Initial Concentration (mg/l)	186.5	95.5	48	24	9.65	4	1	0.12
		Final Concentration (mg/l)	112	52	22	8.2	1.8	0.59	0.2	0.11
		Adsorbed Concentration (ug/g)	745	435	260	158	78.5	34.1	8	0.1
UOS-SS18	2-3'	Initial Concentration (mg/l)	186.5	95.5	48	24	9.65	4	1	0.12
		Final Concentration (mg/l)	77	27	5.8	1.9	0.36	0.27	0.13	0.15
		Adsorbed Concentration (ug/g)	1095	685	422	221	92.9	37.3	8.7	-0.3

Note: Negative adsorption concentrations represent metal(s) leaching from soils.

Color indicates surface soil site and monitoring well proximity.

Source: Appendix 7, Phase I RFI Report, ACI 2003.



20 yr simulation

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

SIMULATED ARSENIC CONTRIBUTION FROM
SHALLOW PLANT SITE SOILS

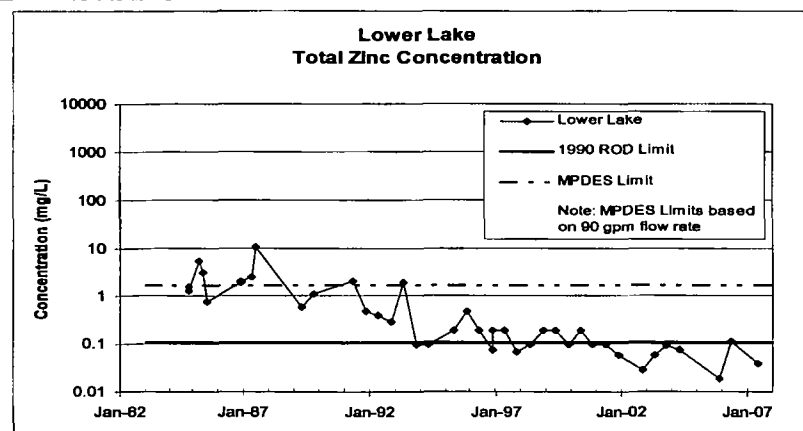
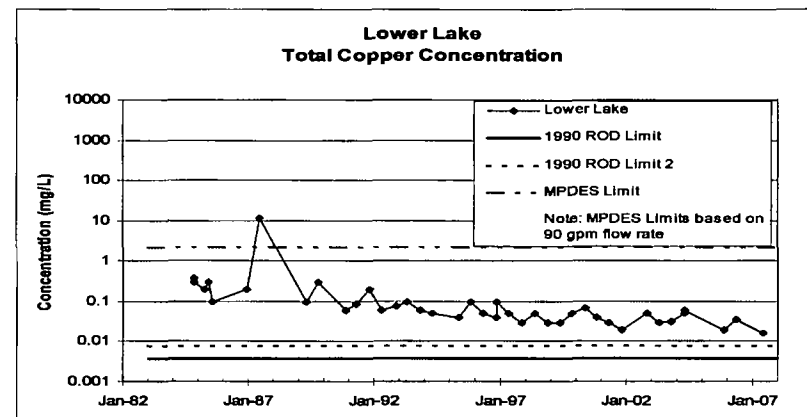
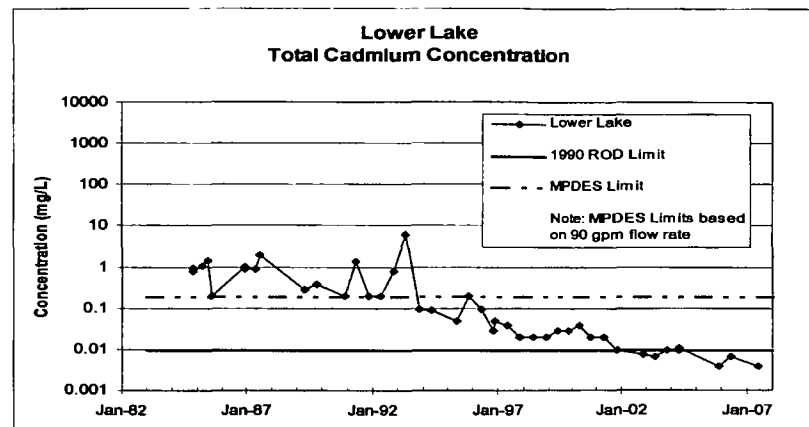
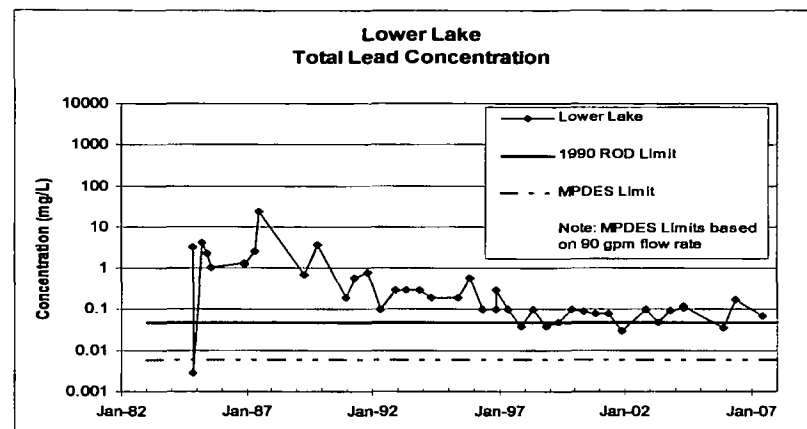
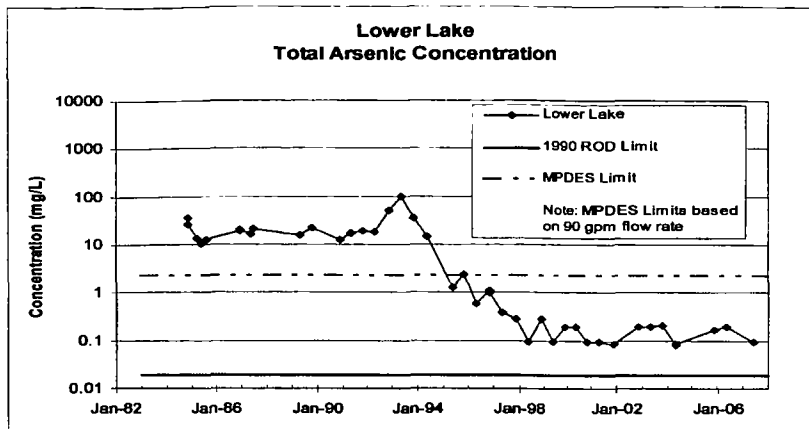
FIGURE
10-2

elevated concentrations in the former acid plant sediment drying area. This area has since been isolated by construction of a slurry wall in 2006 (Figure 10-2).

Figure 10-3 shows water quality in Lower Lake. MPDES limits shown on Figure 10-3 represents the discharge limits from HDS water treatment plant which discharges into Lower Lake. As the figure shows, Lower Lake has shown a generally steady trend of water quality improvements in recent years for most of the monitored parameters. Cadmium and zinc generally are below CERCLA ROD limits in recent years, and lead is generally near or below limits. Copper show a steady but slow improving trend over the last 15 years and projection of this trend suggests improvement that would meet ROD limits in about 15 additional years. Arsenic shows a relatively flat pattern in recent years and concentrations remain near the 0.1 mg/l level. This is similar to the concentrations observed in the fill between Upper Lake and Lower Lake and suggests groundwater flow through the fill may be influencing arsenic concentration trends in Lower Lake. However, establishment of the three flow conveyances to channel flow through the fill between Upper Lake and Lower Lake, along with the cover system as described in Section 10.3, may significantly improve these generally positive water quality improvement trends, and should allow Lower Lake water quality to meet CERCLA ROD limits.

10.1.1 Flow Conveyance Design and Installation

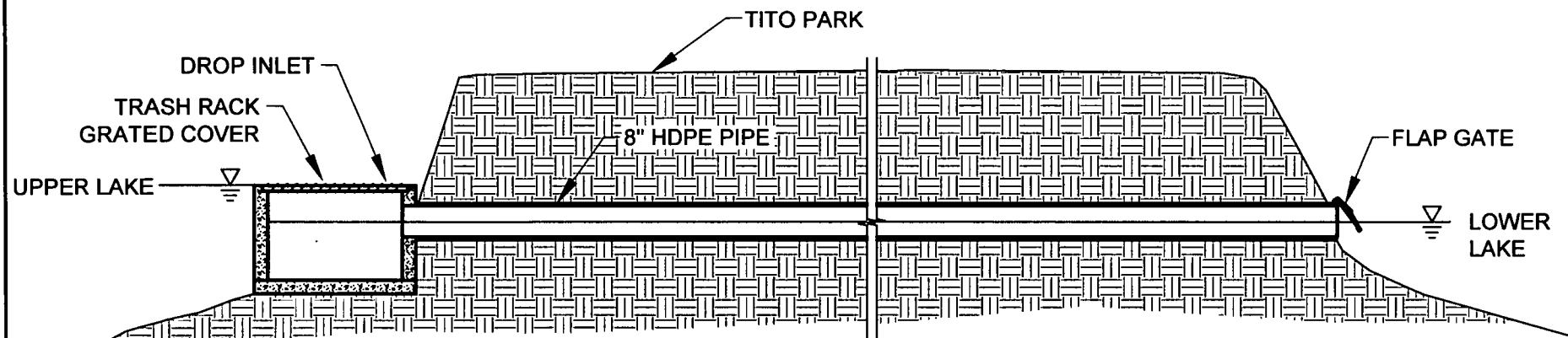
Figure 10-4 shows general conveyance details. The conveyances will be constructed of 8-inch diameter HDPE pipe. Water levels and flows between Upper and Lower Lake will be controlled by a drop pipe inlet installed on the Upper Lake side of the culverts and by back-flow control gates (Flap-gates) located on the Lower Lake side (Figure 10-4). Drop-inlets on the pipes will allow water to flow out of Upper Lake and into Lower Lake when water level rise in Upper Lake.



**ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN**

**WATER QUALITY TRENDS
IN LOWER LAKE**

**FIGURE
10-3**



ASARCO EAST HELENA SMELTER
 COVER SYSTEM DESIGN

GENERAL CONVEYANCE
 DETAIL

FIGURE

10-4

10.1.2 Installation Schedule

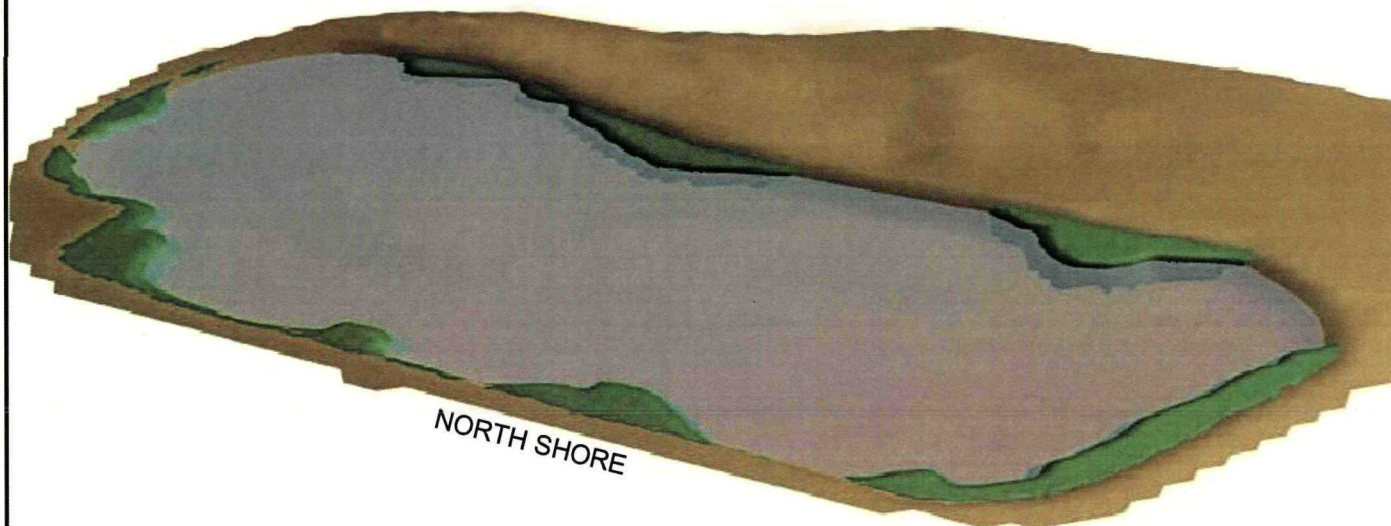
The conveyances will be installed in calendar year 2008, before implementation of the shoreline improvements (see Section 10.2) and the cover system in the fill area between Upper and Lower Lake (see Section 10.3). This approach allows supplemental monitoring of Lower Lake and groundwater in the fill area and allows assessment of the effectiveness of this approach before the engineered cover is installed in the area.

10.2 PHASE 2

As shown in Figure 10-1, Phase 2 will supplement established native and naturalized vegetative communities that are developing along the 10- to 15-foot wide perimeter of Lower Lake and northern portions of the Upper Lake shoreline. This will involve grading and reshaping of the shoreline and capping with suitable cover soil. The material removed from the grading and reshaping of the shoreline will be integrated under the multi-layered cover system. In addition to supplementation of natural vegetation, fill will be added to portions of the Lower Lake perimeter to create an irregular, sinuous shoreline and introduce new wetland and wildlife habitat while potentially improving water quality. A tree and shrub screen similar to that established along the western shoreline of Lower Lake in 1997 will be planted along a northwestern portion of the Upper Lake shoreline. The permanent site security fence will be constructed along this screen to supplement the vegetative barrier between the cover system and Upper Lake.

10.2.1 Earthwork and Shoreline Improvements

To ensure the success of revegetation efforts, site conditions that have precluded the establishment of vegetation on barren shoreline locations will be identified. Shoreline bank slopes will be reduced where slopes exceed 3:1 in steepness. Field stone and gravel will be placed into Lower Lake to contour the lake shoreline, creating shelter and shallows (Figure 10-5). Shoreline areas will be capped to within 12 to 18 inches of the water line with suitable coversoil. Coversoil suitability criteria are presented in Table 10-4. The shoreline area between the coversoil and water line will be armored with 12-inch nominal riprap to minimize erosion by wave action.



LOWER LAKE WITH SHORELINE IMPROVEMENTS



LOWER LAKE PRIOR TO SHORELINE IMPROVEMENTS

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

**EARTHWORK AND SHORELINE
IMPROVEMENTS ON LOWER LAKE**

FIGURE

10-5

TABLE 10-4. COVERSOIL SUITABILITY CRITERIA

Parameter	Suitable Standard
pH	5.5 - 8.5
Electrical Conductivity	< 4 mmhos / cm
Sodium Adsorption Ratio	< 12
Acid-Base Potential	> -5 T / 1000T
C:N Ratio	< 20 : 1
Soil N	> 15 ug NO ₃ -N / g
Soil P	> 10 ug P / g (Bray extraction)
Soil K	> 75 ug K / g
Organic Matter	1 - 10 %
Saturation %	20 - 80 %
% Coarse Fragment Content	< 20 %
Texture	Loam Silt loam (sand > 15 %) Silty clay loam (clay < 35 %, sand > 15 %) Clay loam (clay < 35 %) Sandy clay loam Sandy loam

10.2.2 Revegetation of Shoreline Areas

The focus of revegetation efforts will be to supplement established native and naturalized vegetative communities that have developed along the 10- to 15-foot wide perimeter of Lower Lake and parts of Upper Lake north and west shorelines. Revegetation will result in the establishment of sustainable vegetative communities that are comparable to adjacent, undisturbed communities in the Upper Lake area. A preliminary inspection of the area in January 1997 (Hydrometrics, 1997) identified wetland and riparian habitats that may be used as a reference area for revegetation planning and success quantification. Habitats and vegetation species observed during the preliminary inspection are listed in Table 10-5.

**TABLE 10-5. WETLAND/RIPARIAN HABITATS AND VEGETATION SPECIES
OBSERVED IN THE UPPER LAKE AREA, JANUARY 1997**

Scrub-Shrub Wetland	
Willow	<i>Salix spp.</i>
Alder	<i>Alnus spp.</i>
Red-twig dogwood	<i>Cornus stolonifera</i>
Reed canary grass	<i>Phalaris arundinacea</i>
Western wheatgrass	<i>Agropyron smithii</i>

Emergent Wetland	
Cattail	<i>Typha latifolia</i>
Reed canary grass	<i>Phalaris arundinacea</i>
Giant wildrye	<i>Elymus cinereus</i>

Mesic Shrub	
Willow	<i>Salix spp.</i>
Alder	<i>Alnus spp.</i>
Russian Olive	<i>Elaeagnus angustifolia</i>
Boxelder	<i>Acer negundo</i>
Woods rose	<i>Rosa woodsii</i>
Red-twig dogwood	<i>Cornus stolonifera</i>
Western wheatgrass	<i>Agropyron smithii</i>

To ensure revegetation success and ecosystem continuity, selected Upper Lake wetland/riparian vegetation communities will be utilized as sources for vegetative transplants (cuttings and live clumps) to SEP locations at Upper and Lower Lake shoreline sites. These transplants will be collected on a low-density, dispersed basis (minimum of 15 feet between collections) throughout accessible portions of the Upper Lake area. Sites that are disturbed by these collection activities will be graded and seeded with annual rye and western wheatgrass. These grasses will provide interim cover for natural regeneration. Establishment of vegetation on remaining shoreline areas will be accomplished through seeding and transplanting using commercial Montana seed/nursery sources. To increase diversity and further enhance wildlife habitat, native plant species listed in Table 10-6 may be used along Upper and Lower Lake shorelines.

**TABLE 10-6. ADDITIONAL NATIVE PLANT SPECIES
PROPOSED FOR ESTABLISHMENT IN UPPER AND
LOWER LAKE WETLAND/RIPARIAN HABITATS**

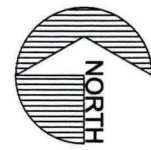
Scrub-Shrub Wetland	
Black cottonwood	<i>Populus trichocarpa</i>
Douglas hawthorn	<i>Crataegus douglasii</i>
Tufted hairgrass	<i>Deschampsia caespitosa</i>
Emergent Wetland	
Sedge	<i>Carex spp.</i>
Rush	<i>Juncus spp.</i>
Bulrush	<i>Scirpus spp.</i>
Arrowhead	<i>Sagittaria spp.</i>
Mesic Shrub	
Snowberry	<i>Symphoricarpos albus</i>
Serviceberry	<i>Amelanchier alnifolia</i>
Douglas hawthorn	<i>Crataegus douglasii</i>
Tufted hairgrass	<i>Deschampsia caespitosa</i>

10.3 PHASE 3

As shown in Figure 10-6, Phase 3 will establish an upland vegetative community in the area between Upper and Lower Lakes. This will involve covering the area with suitable coversoil (see Table 10-1) prior to revegetation with grasses. Revegetation activities will include the introduction of a sensitive plant species (lesser rushy milkvetch) at selected site locations to expand the range and population of this species. Trees and shrubs will be added along riparian fringe locations to enhance the quality of the upland habitat.




10.3.1 Earthwork and Upland Improvements

Fill will be used as needed to raise the area between the lakes and will be graded to improve its upland features and to promote drainage off the multi-layered cover system. Naturalized topography that enhances upland habitat for vegetation and wildlife between Upper and



SCALE
(In Feet)
0 120

LEGEND

-  EARTH WORK PERFORMED DURING RIPARIAN AREA ENHANCEMENTS (SEE FIG. 10-1)
-  TOPSOIL AND GRASS
-  NEW TREES AND SHRUBS

ASARCO EAST HELENA SMELTER
COVER SYSTEM DESIGN

UPLAND AREA ENHANCEMENTS

FIGURE

10-6

Lower Lake will be accomplished by increasing the amount of common borrow on top of the liner. The area will then be covered with six inches of topsoil and revegetated.

10.3.2 Revegetation of Upland Areas

Revegetation of the area between the lakes will create a foothill grassland community comparable to established communities of this type in the East Helena area. Blending of this upland area into the planned Upper and Lower Lake wetland/riparian communities will create wildlife habitat opportunities. A preliminary inspection of the area in January 1997 (Hydrometrics, 1997a) identified occurrences of upland habitat that could be used as reference areas for revegetation planning and success quantification. These habitat and vegetation species, observed at several locations during the preliminary inspection, are listed in Table 10-7.

**TABLE 10-7. UPLAND HABITAT AND VEGETATION SPECIES OBSERVED IN
THE EAST HELENA AREA, 1997**

Foothill Grassland	
Bluebunch wheatgrass	<i>Pseudoroegneria spicata</i>
Thickspike wheatgrass	<i>Agropyron dasystachyum</i>
Blue grama	<i>Bouteloua gracilis</i>
Idaho fescue	<i>Festuca idahoensis</i>
Needle-and-thread grass	<i>Stipa comata</i>
Sunflower	<i>Helianthus annuus</i>
Yarrow	<i>Achillea millefolium</i>

Revegetation of the area between the lakes will be accomplished through seeding and transplanting using commercial Montana seed/nursery sources. Additional native plant species are proposed for introduction to the area community in order to increase diversity and further enhance wildlife habitat. Native species under preliminary consideration are listed in Table 10-8.

**TABLE 10-8. ADDITIONAL NATIVE PLANT SPECIES PROPOSED
FOR UPLAND HABITAT ESTABLISHMENT IN THE AREA
BETWEEN UPPER AND LOWER LAKES**

Foothill Grassland	
Rough fescue	<i>Festuca scabrella</i>
Sandberg bluegrass	<i>Poa sandbergii</i>
Prairie coneflower	<i>Ratibida columnifera</i>
Lesser rushy milkvetch	<i>Astragalus convallarius</i>

The introduction of lesser rushy milkvetch will serve to expand the range and population of this species in the East Helena valley to which it is endemic. Lesser rushy milkvetch is classified by the Montana Natural Heritage Program (Lesica and Shelly, 1991) as a sensitive species. This plant has no statutory federal or state protection (Lesica and Shelly, 1991). Establishment of a population of lesser rushy milkvetch will be conducted as a trial introduction, pending input from appropriate resource organizations (state/federal agencies, the Montana Natural Heritage Program and the Montana Native Plant Society) and the successful location/propagation of this species.

10.3.3 Visual Screen

A shelterbelt planting of trees and shrubs will be installed along the riparian fringe at the west end of Lower Lake and along the northwest corner of Upper Lake. Shelterbelt species under consideration include box elder, Rocky Mountain juniper and Russian olive. The area will also be seeded to foothill grassland species (Table 10-7). The completion of this planting will result in a continuous row of trees and shrubs. Trees and shrubs creating a physical screen along the northwest side of Tito Park and Upper Lake were proposed in the SEP, but have been removed from this plan. The original intent of trees and shrubs as a physical screen was to block out noise from the operating plant. Due to the fact that a noise barrier is no longer necessary and plants on the cover system may compromise its integrity, these plants have been removed from the plan.

11.0 SCHEDULE

A schedule for implementing the Cover System for 2008 is dependent upon sequencing the: 1) soils sampling, excavation and confirmatory sampling for exposed areas, 2) demolition and soil sampling for the blast furnace and Monier flue, and 3) 2008 Montana cleaning and demolition program. The 2008 Cover System schedule is contained in Figure 11-1. Key schedule events include:

- Construction of the CAMU
- Pre-demolition Cleaning
- Demolition of structures
- Stack demolition
- Flue demolition
- Flue dust removal and associated impacted soils from exposed soil areas and
- Interim Cap.

FIGURE 11-1. COVER SYSTEM DESIGN SCHEDULE
ASARCO EAST HELENA SMELTER



12.0 REFERENCES

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- U.S. Department of the Army, Corps of Engineers, 2005. HEC-RAS River Analysis System, Generalized Computer Program. Hydrologic Engineering Center, Davis, California. May, 2005.

APPENDIX A

SPECIFICATIONS

PROJECT SPECIFICATIONS

The Standard Specifications for Road and Bridge Construction, edition of 2006, prepared by the Montana Department of Transportation and Montana Transportation Commission, hereinafter referred to as the "Standard Specifications," shall be applied to Project work as specified below and shall govern this Project and form the basis of this Contract, except as modified in these Contract Documents. Contractor shall note the 2006 Standard Specifications shall be used as modified herein without subsequent amendments or newer publications made by the Montana Department of Transportation and Montana Transportation Commission. The Standard Specifications are modified herein as detailed in the following divisions. Division and subdivision numbers refer to corresponding numbers of the Standard Specifications. Additional division or sections numbers may be used to specify items of work not included in the Standard Specifications.

Copies of the 2006 Standard Specifications may be obtained from Montana Department of Transportation, Contract Plans Section, 2701 Prospect Avenue, P.O. Box 201001, Helena, Montana 59620-1001, Telephone (406) 444-6215 or at www.mdt.mt.gov/business/contracting/standard_specs.shtml

DIVISION 200 - EARTHWORK

DIVISION 600 - MISCELLANEOUS CONSTRUCTION

DIVISION 700 - MATERIALS

DIVISION 200 – EARTHWORK

SECTION 203 - EXCAVATION AND EMBANKMENT:

Add the following subsections to this section.

203.06 DESCRIPTION OF PROJECT EARTHWORK

This specification covers the requirements for labor, supervision, equipment and materials associated with the earthwork operations shown on or implied by the design Drawings, or herein specified. Earthwork activities shall include, but not be limited to project layout, soil testing, site drainage, dust control, clearing, disposal, excavation, subgrade preparation, protection and removal of known underground utilities, fill and backfill, embankments, finish grading and site restoration.

203.07 CONSTRUCTION REQUIREMENTS OF PROJECT EARTHWORK

203.07.1 Grade Control and Layout of Work

The Contractor shall furnish all stakes, markers, tools, equipment and labor required to lay out the work from bench marks and/or control point markers indicated on the drawings. The Contractor shall not disturb existing survey monuments or bench marks without the consent of the Engineer. Markers that are accidentally disturbed by earthwork operations shall be replaced at the Contractor's expense by a licensed land surveyor. Copies of all survey notes will be given to the Engineer within one day after survey is conducted. Restaking and remarking of layout stakes caused by misinterpretation of the specifications will be at the Contractor's expense. It is recommended that the surveyor meet with the Engineer to review grades and dimensions, prior to commencing layout surveys.

203.07.2 Inspection and Testing

The Owner may employ independent engineering firms for Quality Assurance inspection and testing. Contractor shall cooperate with the Owner's oversight personnel. The Owner will pay for Quality Assurance testing. However, if initial testing indicates that the Contractor has not complied with the Contract Documents, then the costs of subsequent testing associated with the non-compliance will be deducted from the Contract price.

The Contractor is required to conduct Quality Control testing. Costs for these tests will be paid by the Contractor.

203.07.3 Protection and Safety

Open Excavations. Provide barricades and/or other safety equipment as required to protect any equipment, vehicles and workers from any open excavation.

- A. Protection of Property. The Contractor shall protect adjacent property and avoid damage to such property. Adjacent property damaged due to the Contractor's operations shall be repaired or replaced. The repairs and/or replacement shall be equal to existing improvements and shall match existing finish and dimensions.
- B. Utilities. The Contractor is responsible for obtaining off-site utility locations as required by law. He will notify the Engineer prior to digging adjacent to utilities.

203.07.4 Subgrade and Fill Protection

During construction, fills and excavations shall be kept shaped and drained. Ditches and drains along subgrade shall be maintained in such a manner as to drain effectively at all times.

Finished subgrade shall not be disturbed by traffic or other operations and shall be protected and maintained by the Contractor until completion and acceptance of the work. The storage or stockpiling of materials on the finished subgrade will not be permitted.

203.07.5 Site Drainage

Excavation, fill and backfill work areas shall be continually and effectively drained. Water shall not be permitted to accumulate in excavations or foundation areas. The Contractor shall construct suitable dikes, drains or provide pumping equipment, as required, to divert water flows away from the work areas.

203.07.6 Dust Control and Haul Road Maintenance

Control all dust produced from the project site. Prevent the spread of dust and avoid creation of a nuisance in the surrounding area. The Contractor shall prepare and submit a Dust Control Plan to the Owner for approval before construction begins. The Dust Control Plan will address methods to be used to minimize dust during sodding, hauling waste placement, grading and earthwork operations. It will also describe haul road sweeping and maintenance operations.

203.07.7 Excavation

- A. General Requirements. The Contractor shall excavate every type of material encountered within the limits of the project, to the lines, grades and elevations indicated and as specified herein.
- B. Excavations for Ditches and Drainage Structures. Excavations for ditches and drainage structures shall be accomplished by cutting accurately the line, grade and cross-section required. Trenches and pits shall be of sufficient size to accommodate the installation of piping and structures. Excessive open ditch excavation shall be backfilled with satisfactory materials to the grades shown on the design Drawings. The Contractor shall

maintain all excavations free from detrimental quantities of brush, sticks, trash and other debris.

C. Subgrade Preparations

1. **General Requirements.** Subgrade shall be shaped to the line, grade and cross-section and compacted as specified for all required embankments. This operation shall include plowing, disking and any moistening or aeration required to obtain proper compaction. Soft or otherwise unsatisfactory material shall be removed and replaced with satisfactory material as directed by the Engineer.

Low areas resulting from the removal of unsatisfactory material shall be brought up to the required grade with satisfactory materials, and the entire subgrade shall be shaped to the line, grade and cross-section and compacted as specified.

After rolling, the elevation of the finished subgrade shall not vary more than 0.2 foot from the established grade and approved cross-section.

2. **Compaction.** Compaction shall be accomplished by sheepfoot rollers to at least 90 percent of Proctor maximum dry density.

203.07.8 **Embankment**

A. Materials

1. **Compacted Slag.** Compacted slag shall be placed between the installed cover systems and the plant site ground surface to promote drainage of the liner system. The compacted slag material shall vary in depth throughout the site and act as a cushion material. At a minimum, the top 6" shall be ripped slag.
2. **Excavated Soils.** Soils removed from the soil removal area of the plant will be used as backfill materials.
3. **Topsoil and Subsoil.** The Contractor shall obtain topsoil and subsoil from clean sources. Topsoil shall be free of trash, rocks, hard lumps of soil, and stubble. Subsoil shall be free of sharp or jagged rocks, roots, and debris.

B. Compaction

1. **Compacted Slag and Excavated Soils.** The Contractor shall compact the crushed slag by rolling using vibratory compaction equipment with a static weight of 15 tons. Two coverages shall be completed for each 12-inch lift.
2. **Subsoil.** The Contractor shall lightly roll the subsoil using nonvibratory compaction equipment with a static weight of 1.5 tons or less to ensure its stability under equipment traffic. Carefully roll the layer under the guidance of the Engineer to ensure that the underlying flexible membrane liner is not damaged.

D. Finish Grading

The surface of all excavation, fill, embankment and subgrade shall be finished to a reasonable smooth and compact surface in accordance with the lines, grades and cross-sections shown. The degree of finish for all graded areas shall be within 0.2 foot of the grades and elevations indicated. Gutters and ditches shall be finished in manner that will result in effective drainage.

203.07.9 Monitoring Wells

All monitoring wells shall be protected at all times and shall not be damaged during construction. Contractor shall be responsible to reimburse the Owner should well replacement be necessary due to Contractor activities. All well extensions and completions shall be vertical and maintain the integrity of the existing PVC casing. All well extensions shall be done by a licensed monitoring well constructor in accordance with Montana Department of Natural Resources and Conservation (MDNRC) monitoring well construction requirements. Extended wells must be surveyed in by a licensed surveyor to determine the new casing elevation.

END OF SECTION

DIVISION 600
MISCELLANEOUS CONSTRUCTION

SECTION 613 RIPRAP AND SLOPE AND BANK PROTECTION

613.02 MATERIALS

Replace with the following paragraph.

Furnish stone that is hard, durable, sound, angular in shape, resistant to weathering and to water action; free from overburden, spoil, shale, structural defects, and organic material. The least or nominal dimensions of any stone shall not be less than 1/3 its greatest dimension. Unless otherwise permitted, the bulk density of the stone shall be 165 pounds per cubic foot, with a specific gravity of 2.65. All stone shall meet specifications for limits of total metals.

GRADATIONS

Stone materials shall meet the following gradation requirements:

Sieve Designation	Percent Passing
15-inch	95-100
12-inch	40-60
8-inch	0-10

This gradation may be adjusted only with approval of the Owner's Representative.

TOTAL METALS SAMPLING

All stone sources shall be shown to be free of deleterious amounts of heavy metals through sampling and analysis for heavy metals. Two total metals samples shall be collected from each separate stone source and submitted for total metals laboratory analysis. The concentrations of the following elements shall be determined: arsenic, cadmium, copper, lead, mercury, and zinc.

<u>Element</u>	<u>Total Concentration (milligrams per kilogram)</u>
Arsenic	30
Cadmium	4
Copper	100
Lead	100
Mercury	5
Zinc	250

Sample results shall be submitted to the Owner's Representative and approved by the Owner's Representative before any rock is brought to the site. If concentrations greater than the above levels are found, the material shall be rejected and another rock source shall be found and tested for acceptance.

PLACING

Rock slope protection shall be placed in accordance with the following method:

A footing trench shall be excavated along the toe of the slope as shown on the plans. Rocks shall be so placed as to provide a minimum of voids and the larger rocks shall be placed in the toe course and on the outside surface of the slope protection. The rock may be placed by dumping and may be spread in layers by bulldozers or other suitable equipment. Local surface irregularities of the slope protection shall not vary from the planned slopes by more than 0.3-m measured at right angles to the slope. At the completion of slope protection work, the footing trench shall be filled with excavated material and compaction will not be required.

SECTION 622 GEOSYNTHETICS CONSTRUCTION

622.01 MATERIALS

Replace with the following paragraph.

Furnish materials meeting the following requirements:

Geotextiles	Subsection 716.01
Geomembranes	Section 624
Geocomposite	Section 625
GCL	Section 626

SECTION 624 FLEXIBLE MEMBRANE LINER (FML)

Add the following new section.

624.01 DESCRIPTION

A. Scope. The work covered by these Specifications consists of furnishing and installing a polyvinyl chloride (PVC) flexible membrane liner where shown on the Drawings.

B. Definitions used in this section.

1. **Air Lance**. Consists of a stream of air forced through a 3/32" air nozzle at the end of a hollow metal tube for conducting a commonly used nondestructive test method to determine seam continuity and tightness of relatively thin, flexible geomembrane.
2. **Bodied Chemical Fusion Agent**. A chemical fluid containing a portion of the parent geomembrane that, after application of pressure and after the passage of time, results in the chemical fusion of two essentially similar geomembrane sheets, leaving behind only that portion of the parent material.
3. **Geomembrane**. An essentially impermeable synthetic membrane used as a solid or liquid barrier. Synonymous term for flexible membrane liner (FML).

4. **Seaming Boards.** Smooth wooden boards, conveyor belt, or similar hard surface (preferably 1" X 12" X 8', or more), placed beneath the area to be seamed to provide a uniform surface to apply roller pressure in the fabrication of field seams.
5. **Tensiometer.** A device containing a set of opposing grips used to place a geomembrane seam in tension for evaluating its strength in shear or in peel.
6. **Vacuum Box Assembly.** Consists of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole, or valve assembly, and a vacuum gauge for conducting a nondestructive test method which develops a vacuum in a localized region of a geomembrane seam in order to evaluate the seam's tightness and suitability.

624.02 QUALITY ASSURANCE

A. Fabricator/Installer Qualifications

1. The installer shall have worked in a similar capacity on at least five (5) projects similar in complexity to the project described in the Contract Documents and with each project involving at least 100,000 square feet of a similar product.
2. Installation supervisor/field engineer shall have worked in a similar capacity on at least two (2) jobs similar in size and complexity to the project described in the Contract Documents.
3. The manufacturer shall perform the quality control tests listed in Table 4 at the manufacturing plant. Provide all quality control certificate to the Engineer as specified in Section 624.03(B) of these Special Provisions.

TABLE 4. GEOMEMBRANE SPECIFICATIONS

PROPERTY	TEST METHOD	REQUIREMENT
		CAP
Gauge (mils nominal)	ASTM D 1593	40
Tear Strength (pounds)	ASTM D 1004 or ASTM D 751	10
Tensile Strength	ASTM D 882	
1. Machine direction (lb/in)		97
2. Cross-machine direction (lb/in)		97
Hydrostatic Resistance (lb/in ²)	ASTM D 751	120

B. Delivery, Storage and Handling

1. Deliver geomembrane to the site only after the Engineer receives and approves the required submittals. Immediately remove damaged or unacceptable material from the site and replaced at no cost to the Owner.
2. Store geomembrane on pallets to protect from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, direct heat of the sun or other damage. Stack geomembrane no more than 3 rolls or 1 pallet high.
3. Repair all geomembrane damaged during handling to the satisfaction of the Engineer. Immediately remove from the site and replace geomembrane determined by the Engineer to be irreparably damaged. Repair, removal and replacement shall be solely at the Contractor's expense.

C. Warranty

1. The geomembrane installer shall warrant his workmanship to be free of defects for one (1) year after final acceptance of the work. This warranty shall include, but not be limited to, all seams, anchor trenches, geomembrane attachments to appurtenances, and penetration seals. The installer shall also obtain and furnish the Owner a material warranty from the geomembrane manufacturer. The material warranty shall be for defects or failure due to weathering for ten (10) years after final acceptance.
2. Should a defect or failure occur within the aforesaid periods, the installer shall bear all costs for repair and/or replacement of the geomembrane and shall in addition bear all costs for the excavation of any cover backfill that is required to be removed in order to repair and/or replace the geomembrane. All materials removed to allow repairs to be made shall be reinstalled by the installer in accordance with these Contract Documents.

624.03 SUBMITTALS

- A. Submit the following documents to the Engineer no later than three (3) weeks prior to installation of the geomembrane:
1. Complete written instructions for storage, handling, installation and seaming of the geomembrane which are in compliance with the Specifications and conditions of warranty.
 2. Panel layout drawings showing both fabricated and field seams, and details not conforming with the Drawings (if any).
 3. Qualification of the geomembrane installer, including the resume of the field engineer installation supervisor to be assigned to this project, including dates and duration of employment.
 4. Installer's Quality Control Manual.

B. Submit the following documents to the Engineer prior to the shipment of the geomembrane to the site.

1. Polymer compound data

- a) Statement of production date or dates.
- b) Laboratory certification that the materials meet Specifications.
- c) Certification that all materials are from the same manufacturer.
- d) Copy of quality control certificates issued by manufacturer.
- e) Statement that no reclaimed polymer is added to the compound.

2. Geomembrane data.

- a) Statement of production date or dates
- b) Laboratory certification that the materials meet the Specification.
- c) Copy of quality control certificates issued by the manufacturer.
- d) Reports of tests defined in Table 5-1 from the manufacturer.

TABLE 5-1. MANUFACTURER'S QA TESTS FOR FML

Property	Test Method	Test Frequency	Test Standard(1)	Rejection Criteria
			PVC 40 mil	
Gauge (mils nominal)	ASTM D 1593	1 per lot	40	Material must meet all standards <u>before</u> delivery to site
Tear Strength (pounds)	ASTM D 1004		10	
Tensile Strength	ASTM D 882		97	
3. Machine direction (lb/in)			97	
4. Cross-machine direction (lb/in)			97	
Hydrostatic Resistance (lb/in ²)	ASTM D 751		120	
Specific Gravity	ASTM D 792	≥1.2		

Notes:

- (1) Values shown are minimum average roll values.

C. Submit the following to the Engineer prior to start of the FML installation:

1. Warranties for material and installation as specified hereinafter for review to the Owner.
2. Certificate of acceptance of prepared subgrade for each area to be covered by an PVC FML, signed by the installation supervisor.

D. During installation, submit to the Engineer results of Contractor quality control testing as specified in 624.06 TESTING.

E. Upon completion of the installation, submit to the Engineer the following:

1. Certificate stating the geomembrane has been installed in accordance with the Contract Documents.
2. Manufacturer's and Installer's warranties as specified hereinafter.
3. Record drawings showing location of panels, seams, repairs, patches, and destructive samples, including detailed measurements.

624.04 MATERIALS

A. Description of Materials

1. Geomembrane liner shall be top quality products, recommended by the manufacturer for this specific type of work, and shall have been satisfactorily demonstrated by prior use to be suitable and durable for such purposes.
2. Extrudate Rod or Bead shall be made from the same resin as the geomembrane liner with carbon black. Additives shall be thoroughly dispersed in the extrudate.

B. Physical Characteristics

The PVC geomembrane liner:

1. Shall be formulated from a polyvinyl chloride resin with a specific gravity greater than or equal to 1.2. All resins shall be of the same type and no batch shall be blended with recycles or seconds.
2. Shall be uniform in color, thickness, and size. The material shall be a flexible, durable, watertight product free of pinholes, blisters, holes, bubbles, gels, undispersed resins or carbon black, and other contaminants. Processing aides, antioxidants and other additives shall not exceed a combined maximum total of 1 percent by weight, ignoring carbon black, and 3.5 percent by weight including carbon black.
3. Shall have the minimum physical property characteristics, as outlined in Table 4. Certified test results showing that the sheeting meets or exceeds the Specification shall be submitted per Section 624.03.
4. Shall be supplied in rolls labeled with thickness, length, width, manufacturer, plant location, and identification number.

624.05 INSTALLATION

A. Subgrade Preparation

The subgrade to be lined:

1. Shall be maintained in a dry enough condition for equipment to operate without rutting.
2. Shall be smooth and free of projections and sharp objects that can damage the lining. Remove rocks, hard clods, and other such material, and roll the subgrade so as to provide a smooth compact surface. The smoothed subgrade will limit liner bridging to less than 1 inch.
3. Shall be inspected prior to geomembrane installation to ascertain its suitability for installation in compliance with the terms of the product warranty and the requirements of this Specification. For PVC geomembranes, submit to the Engineer a signed certification that the prepared subgrade surface is satisfactory. Installation of geomembrane without providing written certification shall constitute acceptance of the subgrade by the Contractor.
4. Shall have round edges at anchor trenches or edges shall be cushioned with geotextile and backfill.

B. Geomembrane Installation

1. Only layout the amount of geomembrane that can be seamed during that same day. Assign each panel a simple and logical identifying code number or letter. For PVC geomembrane, identify the panels with each appropriate code on the layout design referenced in 624.03 A.2.
2. Do not damage geomembrane by handling, traffic, or leakage of hydrocarbons or any other means. Do not wear damaging shoes or engage in activities that could damage the geomembrane. Open or unroll geomembrane panels using methods that will not damage, stretch or crimp the geomembrane. Prevent excess condensation on the geomembrane such that the underlying surface is not adversely impacted. Protect underlying surface from damage. Provide sufficient material to allow for geomembrane shrinkage and contraction. Use methods that minimize wrinkles between adjacent panels. Place ballast on geomembrane to prevent uplift from wind. Use ballast that will not damage geomembrane. Do not allow vehicle traffic directly on geomembrane. Remove folded or wrinkled material that exceeds 6 inches in width. Visually inspect geomembrane for imperfections. Mark faulty or suspect areas for testing and/or repair. Any portion of the lining damaged during installation shall be removed or repaired by using an additional piece of the same membrane as specified herein. The liner shall be installed in a relaxed condition and shall be free of stress or tension upon completion of the installation. Stretching the liner to fit is not

permissible. Backfill anchor trenches as soon as possible after installation of liner and geocomposite, if applicable.

3. Place and seam geomembrane only when ambient temperatures, measured six inches above the geomembrane, are between 40 degrees F and 100 degrees F, unless otherwise specified or approved. Installation below 40 degrees F shall occur only after verifying that the geomembrane can be seamed according to Specifications and approval by the Engineer. Do not install geomembrane during precipitation, in the presence of excessive moisture, in areas of ponded water, or in the presence of excessive winds. Protect the geomembrane from wind uplift during installation through the use of sand bags or other suitable weights.

4. Repair all damaged geomembrane and test damaged areas prior to backfilling.

C. Pipe Boots. Fit and seal pipes, manholes, and other penetrations of the geomembrane with shop fabricated boots as shown on the Drawings. Match the flange portion of the boot to the angle of the slope or bottom where the pipe or manhole enters the liner for a smooth fit without excess stretching of the material.

D. Seaming

1. Seam Layout shall:

- a) Orient seams parallel to line of maximum slope, i.e., orient down, not across, slope.
- b) Keep butt seams at least ten (10) feet horizontally away from toe of slope.
- c) For PVC geomembrane, use seam numbering system compatible with panel numbering system.

2. Trial field seaming shall be accomplished by the Contractor on-site for PVC FMLs.

- a) Conduct trial seams on pieces of geomembrane to verify adequate seaming methods and conditions.

- b) Conduct trial seams:

- 1) At beginning of each seaming period;
- 2) At least once for each four seaming hours;
- 3) For each seaming apparatus in use;
- 4) At least once per shift for each person performing seaming; and
- 5) Whenever changes in climatic conditions could effect seam quality.

- c) Make test seam in the location of seaming and in contact with subgrade or geosynthetic (same condition as the geomembrane to be seamed).

- d) Make test seam sample at least two (2) feet long and eleven (11) inches wide with the seam centered lengthwise.
 - e) Cut two, 1-inch wide test strips from opposite ends of the trial seams.
 - f) Cut specimens constant 1-inch wide and clamp at 90 degree angle in tensiometer.
 - g) Quantitatively test field specimens for peel adhesion (ASTM D3083) first, and bonded seam strength (ASTM 3083) second. Insure that these tests are performed in this order.
 - h) A trial seam sample passes when the following results are achieved for both tests.
 - 1) The break is film tearing bond (FTB);
 - 2) The break is ductile; and
 - 3) The strength of break is at least 80% of the specified sheet strength.
 - i) Repeat the trial seam in its entirety if one (1) of the trial seam samples fails in either peel or shear mode.
 - j) Notify Engineer when repeated trial seam fails and do not continue seaming until deficiencies or adverse conditions are determined and corrected, and two (2) consecutive successful trial seams are achieved.
3. Use the following seaming procedure for PVC geomembranes.
- a) Do not begin seaming on liner until all trial seam test samples made by the equipment to be used passes tests as defined above.
 - b) Form seams per manufacturers written instructions. Wipe the contact surfaces of the panels clean to remove all dirt, dust or other substance. Use solvent for cleaning contact surfaces of field joints and for other required uses as recommended by the manufacturer. Apply a hot wedge or hot knife seaming tool to the overlapped panel edges creating a continuous thermal bond between the panels. Smooth out any wrinkles. Field seams shall have a strength of at least 80% of the specified sheet strength.
 - c) Extend seaming to the outside edge of panels to be placed under the anchor berm and in the anchor trench.
 - d) If there is not firm substrate, use a seaming board directly under the seam overlap to achieve proper support.
 - e) If seaming operations are carried out at night, provide adequate illumination.

- f) Cut fish mouths or wrinkles at the seam overlaps along the ridge of the wrinkle in order to achieve a flat overlap. Seam the cut fish mouths or wrinkles and patch any portion where the overlap is less than three (3) inches with an oval or round patch of the same geomembrane extending a minimum of six (6) inches beyond the cut in all directions.
- g) Seam only when ambient temperature, measured 6 inches above the geomembrane is between 40 degrees F and 100 degrees F unless other limits are accepted, in writing, by the Engineer.

E. Defects and Repairs

1. Inspection

- a) During installation and seaming, visually examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of the examination. Mark areas suspected of deficiencies. Remove areas of geomembrane requiring more than one patch per 5,000 square feet and replace at no additional cost to the Owner.
- b) Repair each suspect location both in seam and non-seam areas shall be repaired and non-destructively tested. Do not proceed with work which will cover locations which have been repaired until passing test results are achieved.

2. Repair Procedures

- a) Repair all portions of the geomembrane exhibiting a flaw, or failing a destructive or non-destructive test. Provide a written recommendation for method of repair to the Engineer prior to initiating repair and obtain approval of the repair procedure from the Engineer prior to making repair. Methods which are acceptable to the Engineer and their application are as follows:
 - 1) Capping. Cap for repair of large lengths of failed seams.
 - 2) Patching. Patch large (over 3/8 inch diameter) holes, tears (over 2 inches long), undispersed raw material, and contamination by foreign matter.
 - 3) Remove and Replace. Remove the unsatisfactory material and replace with new material seamed into place.
- b) In addition
 - 1) Abrade surfaces of the geomembrane which need repaired no more than one-half (1/2) hour prior to the repair.
 - 2) Clean and dry all surfaces at the time of repair.

- 3) Extend patches or caps at least six (6) inches beyond the edge of the defect and all corners of patches shall be rounded with a radius of at least three (3) inches.
 - 4) Cut the geomembrane below large caps to avoid water or gas collection between the sheets.
- c) Nondestructively test each repair using the methods described in Section 624.06 of these Special Provisions. Repairs which pass the non-destructive test shall be considered an adequate repair. Large caps shall be of sufficient length to require destructive test sampling, at the discretion of the Engineer. Redo repairs that have failed tests and retest until a passing test results.

624.06 TESTING

A. General

1. Quality control testing, including laboratory testing, field seam testing, and destructive testing in accordance with Table 5-2 shall be performed by the Contractor and observed at the discretion by the Engineer.
2. PVC field seams shall be non-destructively tested over their full length by pressurizing the seam for dual-hot-wedge method seams in the PVC geomembranes, or using a vacuum test unit, air lance, or other approved method for seams in PVC geomembranes where the dual-hot-wedge method could not be used. Non-destructive testing shall be carried out as the seaming progresses, not at the completion of all the field seaming.

B. Vacuum Testing

1. The equipment shall consist of the following:
 - a) A vacuum box assembly.
 - b) A steel vacuum tank and pump assembly equipped with a pressure control and pipe connections.
 - c) A rubber pressure/vacuum hose with fittings and connections.
 - d) A soapy solution and applicator.
2. The following procedures shall be followed:
 - a) Energize the vacuum pump and reduce the tank pressure to approximately ten (10) inches of water.
 - b) Place the box over the wetted seam area (soapy solution).

TABLE 5-2. QUALITY CONTROL CRITERIA FOR FML

Parameter	Test Method	Frequency	Standard	Test Rejection Criteria
Surface Conditions	Visual Inspection	100%	No holes, ridges, voids, rocks, roots, ruts or other non-conformities	Reject and replace all surfaces with any of the items at left
Anchor Trenches	Visual/Tape Measure	100%	See dimensions on project plans	Reject and repair all non-conforming trenches
FML Placement	Visual	100%		Reject and replace non-conforming panels
Seaming	Visual	100%		
Seam Tensile Strength	ASTM D-638	1 per 500 feet of seam	Base material properties – see Table 5-1	Reject and replace non-conforming seams
Seam Shear & Peel	ASTM D-4437	1 per 500 feet of seam	Shear strength: 120 lb/in – 60 mil 80 lb/in – 40 mil Peel strength: 91 lb/in ⁽²⁾ – 60 mil 78 lb/in ⁽³⁾ – 60 mil 60 lb/in ⁽²⁾ – 40 mil 52 lb/in ⁽³⁾ – 40 mil	Reject and replace non-conforming seams
Trial Seam	ASTM D-3083	1) Beginning of each shift of seaming and every four hours thereafter 2) At any change in seam operator, equipment or weather	Break must be a ductile film tear with at least 80% of minimum sheet strength	Repeat trial seaming until standard is met
Air lance Vacuum Box or Internal Pressure	ASTM D-4437 ASTM D-4437 or As described in specifications	100%	Ripples or bubbles Bubbles emerging from seams Loss of pressure ≤4 psi in 7 minutes	Identify, repair and replace leaking seams

Notes:

- (1) Hot wedge seams only
- (2) Extrusion fillet weld only

- c) Ensure that a leak-tight seal is created.
- d) For a period of not less than fifteen (15) seconds, examine the geomembrane through the viewing window for the presence of soap bubbles.
- e) All areas where soap bubbles appear shall be marked and repaired in accordance with repair procedures described in Section 624.05E.
- f) Conduct vacuum testing per ASTM 4437.

C. Air Lance Testing

1. Equipment shall consist of an air lance that can provide a minimum air pressure of 30 psi and a maximum air pressure of 40 psi.
2. The following procedures shall be followed:
 - a) The air nozzle shall be held at a 45 degree angle to the field seam approximately 2" off the edge of the material.
 - b) The air shall be directed toward the seam edge, upper edge and surface to detect loose edges.
 - c) Riffles indicating unbonded areas within the seam or other undesirable seam conditions shall be patched in accordance with repair procedures described in Section 624.05 (E). The patch should then be tested using the same air lance test method.
 - d) Conduct air lance testing per ASTM 4437.

D. Destructive Testing of Seams in PVC FMLs

1. The Engineer will direct the Contractor to perform destructive seam tests at selected locations. The purpose of these tests is to evaluate seam strength. Perform seam strength testing as the seaming work progresses, not at the completion of all field seaming.
2. Location and Frequency
 - a) Collect destructive test samples shall be collected at a minimum frequency of one (1) test location per five hundred (500) feet of seam length, unless otherwise directed by the Engineer.
 - b) Samples, in addition to the minimum frequency, shall be taken as required by the Engineer.

- c) Test location shall be determined during seaming and may be prompted by suspicion of insufficient adhesive, contamination, offsets, or any other potential cause of imperfect seaming. The Engineer will select the locations. The Engineer will not notify the Installer in advance of selecting locations where seam samples will be taken.
 - d) The Engineer reserves the right to increase the frequency in accordance with the actual performance results of samples taken.
3. Sampling Procedure
- a) Samples shall be cut at locations designated by the Engineer as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the panel layout drawing.
 - b) All holes in the geomembrane resulting from destructive sampling shall be immediately repaired in accordance with repair procedures specified in Section 624.05 (E).
4. Size of Samples. The samples shall be eleven (11) inches wide by twenty-four (24) inches long with the seam centered lengthwise. Two (2) 1-inch wide strips shall be cut from each end of the sample and these shall be tested (shear and peel) in the field by the installer. The remaining sample shall be cut into two (2) parts and distributed as follows:
- a) One (1) portion for the Contractor, eleven (11) inches by eleven (11) inches.
 - b) One (1) portion to the Engineer or archive storage, eleven (11) inches by eleven (11) inches
5. Field Testing. The two (2), one (1) inch wide strips described in Section 623.06 (D)(4) shall be tested in the field by the installer and witnessed by the Engineer, by tensiometer, for peel and shear, respectively. Test strips shall meet the peel and shear values specified for trial seams in Section 624.05 (D)(2). If any field test sample fails to pass, then the procedures outlined in that Section shall be applied.
6. Procedures for Destructive Test Failure. The following procedures shall apply whenever a sample fails the destructive test, whether performed by field or laboratory testing:
- a) The seam shall be reconstructed between any two (2) passed test locations, or
 - b) The seaming path can be traced to an intermediate location (at least ten (10) feet minimum from the location of the failed test in each direction) and a small sample taken for an additional field test at each location. If these additional samples pass

the field tests, then full laboratory samples shall be taken. If these laboratory samples pass, then the seam shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam should be reconstructed.

7. Acceptance of Seams - All acceptable seams must be bounded by two (2) locations from which samples passing laboratory destructive tests have been taken. In cases exceeding one hundred and fifty (150) feet of reconstructed seam, a sample taken from within the reconstruction zone must pass destructive testing. Whenever a sample fails, additional testing may be required for seams that were seamed by the same personnel and/or apparatus or seamed during the same time shift.
- E. Geomembrane Wrinkle. When seaming of a geomembrane liner is completed, or when seaming of a large area of a geomembrane liner is completed, and prior to placing overlying materials, the Engineer shall identify the location of excessive geomembrane wrinkles. Wrinkles so identified shall be cut, re-seamed and tested.
- F. Seams That Cannot Be Non-Destructively Tested. The following procedures shall apply to locations where seams cannot be non-destructively tested:
 1. All such seams shall be cap-stripped with the same geomembrane.
 2. If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.
- G. Engineering Observation. If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations shall be observed by the Engineer and Contractor for uniformity and completeness.
- H. Geomembrane Acceptance. The Contractor shall retain ownership and responsibility for the geomembrane until acceptance by the Owner. The geomembrane shall be accepted by the Owner when:
 1. Conformance test results meet the requirements of the Contract Documents.
 2. Required documentation including warranty from the manufacturer, fabricator and installer has been received and accepted.
 3. The installation is complete and accepted by the Engineer.
 4. Verification of the adequacy of all field seams and repairs, including associated testing, is complete.
 5. Written certification documents, including as-built drawings, have been received by the Engineer.

624.07 ANCHORAGE

Anchor liners using edge trenches as shown on the drawings.

SECTION 625 - GEOCOMPOSITE

Add the following new section:

625.01 DESCRIPTION

The work covered by these Specifications consists of furnishing and installing high density polyethylene (HDPE) geonet heat bonded and with one layer of 8 oz/yd² non-woven geotextile where shown on the Drawings or directed by the Engineer.

625.02 MATERIALS

A. Drainage Net

The drainage net shall be manufactured by extruding two sets of polyethylene strands to form a three dimensional structure to provide for planar flow. The drainage net shall be manufactured of polyethylene resin produced in the United States and compounded and manufactured specifically for the intended application. The natural polyethylene resin without the carbon black shall meet the following requirements:

Property	Test Method	Requirements
Density, g/cc	ASTM D 1505 or ASTM D 792	0.945 - 0.955
Melt Index, g/10 min.	ASTM D 1238 Condition E	< 1.0

Labels on each roll shall identify the thickness of the material, the width and length of the roll, lot and roll numbers, and name of the manufacturer. The drainage net rolls shall meet the requirements in this specification.

B. Geotextile

The geotextile shall be a non-woven, needle punched polyester or polypropylene fabric manufactured in the United States for the specific application. The geotextile rolls shall be 15 feet wide and shall meet the requirements in this specification.

C. Geocomposite

The geocomposite shall consist of the HDPE drainage net heat bonded and sandwiched between two layers of geotextile to create a double-sided geocomposite. The geocomposite shall be 13.5 feet wide. The geotextiles shall extend a minimum of 6 inches beyond the edges of drainage net on both sides of the geocomposite roll. The geotextile shall not be bonded to the drainage net within 6 inches from the edges of the rolls.

Materials shall have the minimum physical property characteristics, as outlined in Table 5 and Table 6. Certified test results showing that the sheeting meets or exceeds the Specification shall be submitted per Section 625.03 (E).

TABLE 5. GEONET SPECIFICATIONS

PROPERTY	TEST METHOD	MINIMUM REQUIREMENT
Thickness (mils nominal)	ASTM D-751	250.0
Compressive Strength (pounds/inch ²)	ASTM D 1621	100.0
Transmissivity @ 4000 psf (gal./min./ft.)	ASTM D 4716	0.5

TABLE 6. GEOTEXTILE SPECIFICATIONS

PROPERTY	TEST METHOD	MINIMUM REQUIREMENT
Unit Weight (oz/yd ²)	ASTM D-5261	8
Grab Strength (pounds)	ASTM D 4632	200
Permittivity (sec ⁻¹)	ASTM D 4491	1.3
UV Stability, % ret. (500 hr)	ASTM D 4355	70

625.03 INSTALLATION

A. Surface Preparation

1. Prior to deployment of the geocomposite, the Contractor shall inspect the underlying geomembrane surface to ascertain its suitability for installation in compliance with the terms of the product warranty and the requirements of this Specification.
2. Round edges of anchor trenches as recommended by the geocomposite manufacturer or cushion with geotextiles and backfill.

B. Geocomposite Installation

1. Only install enough panels that can be secured during that same day.
2. Do not damage geocomposite by handling, traffic, or leakage of hydrocarbons or any other means. Do not wear damaging shoes or engage in activities that could damage the geomembrane. Open or unroll geocomposite panels using methods that will not damage, stretch or crimp the geocomposite. Use methods that minimize wrinkles between adjacent panels. Place ballast on geocomposite to prevent uplift from wind. Use ballast that will not damage geocomposite. Repair damage to underlying materials prior to completing deployment of geocomposite. Do not allow vehicle traffic directly on geocomposite. Remove folded material. Visually inspect geocomposite for imperfections. Mark faulty or suspect areas for repair. Any portion

of the geocomposite damaged during installation shall be removed or repaired by using an additional piece of the same geocomposite as specified herein. The geocomposite shall be installed in a relaxed condition and shall be free of stress or tension upon completion of the installation. Stretching the geocomposite to fit is not permissible. Backfill anchor trenches.

C. Securing Geocomposite

1. Seam Layout shall meet the following requirements:

- a) Orient seams parallel to line of maximum slope, i.e., orient down, not across, slope.

2. The seaming procedure used shall be as follows:

- a) Field connections will be made to secure factory fabricated panels or rolls of geocomposite together in the field. Connections shall be formed by lapping the edges of panels a minimum of 2 inches. Any wrinkles shall be smoothed out.
- b) Secure overlapped edges of the geonet by plastic ties approximately every five (5) feet along the panel length. Use plastic ties that are white or a bright color for easy inspection. Do not use metallic ties.
- c) Extend connections to the outside edge of panels to be placed under the anchor berm and in the anchor trench.
- d) If securing operations are carried out at night, provide adequate illumination.

D. Defects and Repairs

1. Inspection

- a) During installation and securing, examine all areas of the geocomposite for defects, tears, undispersed raw materials and all sign of contamination by foreign matter. The surface of the geocomposite shall be clean at the time of the examination. Mark all areas suspected of deficiencies.
- b) Repair each suspect location.

2. Repair Procedures

- a) Repair all portions of the geocomposite exhibiting a flaw by removing the unsatisfactory material and replacing with new material that is overlapped and secured in place.

E. Geocomposite Acceptance. The Contractor shall retain ownership and responsibility for the geocomposite until acceptance by the Owner. The geocomposite shall be accepted by the Owner when:

1. Conformance test results meet the requirements of Table 6-1.
2. Required documentation including warranty from the manufacturer, fabricator and installer has been received and accepted.
3. The installation is complete and accepted by the Engineer.
4. Written certification documents, including as-built drawings, have been received by the Engineer.
5. Submittals shall be the same as those required for geomembrane in Section 623.

TABLE 6-1. CONFIRMATION SAMPLING FOR GEOCOMPOSITES

PARAMETER	TEST	MINIMUM TEST FREQUENCY	REJECTION CRITERIA
Crush Strength	ASTM D-1621	1 per lot ⁽¹⁾	Reject any lot sampling unit or lots that do not meet ASTM-D-4759, Section 5.
Thickness	ASTM D-5199	1 per lot ⁽¹⁾	Reject any lot sampling unit or lots that do not meet ASTM-D-4759, Section 5.
Transmissivity	ASTM D-4716 Width @ 14.5 psi Normal pressure & 0.1 ft/ft hydraulic	1 per lot ⁽¹⁾	Reject any lot sampling unit or lots that do not meet ASTM-D-4759, Section 5.

Notes:

(1) A lot is the smaller of 100,000 square feet or one production run.

SECTION 626 - GEOSYNTHETIC CLAY LINER (GCL)

Add the following new section:

626.01 DESCRIPTION

A. The work covered by these Specifications consists of furnishing and installing geosynthetic clay liner (GCL) where shown on the Drawings or directed by the Engineer.

B. Definitions Used In This Section

Geosynthetic Clay Liner (GCL). A manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetics. The GCL will be reinforced.

Minimum Average Roll Value. The minimum average value of a particular physical property of a material, for 95 percent of all of the material in the lot.

Overlap. Where two adjacent GCL panels contact, the distance measuring perpendicular from the overlying edge of one panel to the underlying edge of the other.

626.02 QUALITY ASSURANCE

1. Manufacture's Qualifications:

The GCL manufacturer must have produced at least 10 million ft² of GCL, with at least 8 million square feet installed.

2. Installer's Qualifications:

The GCL installer must either have installed at least 1 million ft² of GCL, or must provide to the Engineer satisfactory evidence, through similar experience in the installation of other types of geosynthetics, that the GCL will be installed in a competent, professional manner.

3. Product Quality Documentation:

The GCL manufacturer shall provide the Engineer with manufacturing QA/QC certification for each shipment of GCL. The certifications shall be signed by a responsible party employed by the GCL manufacturer and shall include:

- a) Certificates of analysis for the bentonite clay used in GCL production demonstrating compliance with the parameters swell index and fluid loss.
- b) Manufacturer's test data for finished GCL product(s) of bentonite mass/area, GCL tensile strength and GCL peel strength (if applicable) demonstrating compliance with the index parameters.
- c) GCL lot and roll numbers supplied for the project (with corresponding shipping information).
- d) Manufacturer's test data for finished GCL product(s) of GCL index flux, permeability and hydrated internal shear strength data demonstrating compliance with the performance parameters.

4. Delivery, Storage and Handling

- a) Deliver GCL to the site only after the Engineer receives and approves the required submittals. Damaged or unacceptable material shall be immediately removed from the site and replace at no cost to the owner.
- b) Prior to shipment, the GCL manufacturer shall label each roll, identifying:
 - (1) Product identification information (Manufacturer's name and address, brand name, product code).
 - (2) Lot number and roll number.
 - (3) Roll length and weight.
- c) The GCL shall be wound around a rigid core whose diameter is sufficient to facilitate handling. The core is not necessarily intended to support the roll for lifting but should be sufficiently strong to prevent collapse during transit.
- d) All rolls shall be labeled and bagged in packaging that is resistant to photodegradation by ultraviolet (UV) rays.
- e) The manufacturer assumes responsibility for initial loading the GCL. Shipping will be the responsibility of the party paying the freight. Unloading, on-site handling and storage of the GCL are the responsibility of the Contractor, Installer or other designated party.
- f) A visual inspection of each roll should be made during unloading to identify if any packaging has been damaged. Rolls with damaged packaging should be marked and set aside for further inspection. The packaging should be repaired prior to being placed in storage.
- g) The party responsible for unloading the GCL should contact the manufacturer prior to shipment to ascertain the appropriateness of the proposed unloading methods and equipment.
- h) Storage of the GCL rolls shall be the responsibility of the installer. A dedicated storage area shall be selected at the job site that is away from high traffic areas and is level, dry and well-drained.
- i) Rolls should be stored in a manner that prevents sliding or rolling from the stacks and may be accomplished by the use of chock blocks or by use of the dunnage shipped between rolls. Rolls should be stacked at a height no higher than that at which the lifting apparatus can be safely handled (typically no higher than four).
- j) All stored GCL materials and the accessory bentonite must be covered with a plastic sheet or tarpaulin until their installation.
- k) The integrity and legibility of the labels shall be preserved during storage.

5. Warranty

- a) The installer of the GCL to be used in the work shall warrant his workmanship to be free of defects for two (2) years after final acceptance of the work. This warranty shall include, but not be limited to, all seams, anchor trenches, GCL attachments to appurtenances, and penetration seals. The GCL installer shall also obtain and furnish the Owner a warranty from the GCL manufacturer for the materials used. The material warranty shall be for defects or failure due to weathering for 10 years, with temperatures ranging from (-) minus 30 degrees Fahrenheit to (+) plus 110 degrees Fahrenheit, after the completion of the work on a prorata basis.

- b) Should a defect or failure occur within the aforesaid periods, the GCL installer shall bear all costs for repair and/or replacement of the GCL and shall in addition bear all costs for the excavation of any cover backfill that is required to be removed in order to repair and/or replace the GCL. All materials removed to allow repairs to be made shall be reinstalled by the GCL installer in accordance with these special provisions.

626.03 SUBMITTALS

Two copies of the following documents shall be submitted by the Contractor at least three weeks prior to the shipment of the GCL to the site.

1. Conceptual description of the proposed plan for placement of the GCL panels over the area of installation.
2. GCL manufacturer's MQC Plan for documenting compliance of these specifications.
3. A representative sample of the GCLs.
4. A project reference list for the GCL(s) consisting of the principal details for at least ten projects totaling at least 10 million square feet in size.
5. Upon shipment, the Contractor shall furnish the GCL manufacturer's Quality Assurance/Quality Control (QA/QC) certifications to verify that the materials supplied for the project are in accordance with Table 7-1.

626.04 MATERIALS

1. The GCL shall be a needle punched reinforced GCL comprised of a uniform layer of granular sodium bentonite encapsulated between a scrim reinforced non-woven and a virgin staple fiber non-woven geotextile and shall comply with all of the criteria listed in this specification. The needle punched fibers should be thermally fused to the scrim reinforced non-woven geotextile to enhance the reinforcing bond.
2. Reinforced GCL shall be used on this project.
3. The minimum acceptable dimensions of full-size GCL panels shall be 150 feet in length and 13.8 feet in width. Short rolls (those manufactured to a length greater than 70 feet but less than a full-length roll) may be supplied at a rate no greater than 3 per truckload or 3 rolls every 36,000 square of GCL, whichever is less.
4. A 12 -inch overlap guideline shall be imprinted on both edges of the upper geotextile component of the GCL as a means for providing quality assurance of the overlap dimension. Lines shall be printed in easily visible, non-toxic ink.
5. The granular bentonite or bentonite sealing compound used for seaming, penetration sealing and repairs shall be made from the same natural sodium bentonite as used in the GCL and shall be as recommended by the GCL manufacturer.

TABLE 7-1. ACCEPTANCE TESTING FOR GCL

Parameter	Test Method	Frequency	Test Standard	Rejection Criteria
Mass per Unit Area	ASTM D-5993	1 per lot ⁽¹⁾	0.75 lb/ft ² MIN	Materials must pass all acceptance testing before delivery to site
Hydraulic Conductivity	ASTM D-5887		5×10^{-9} cm/sec MAX	
Shear Strength	ASTM D-5321		500 psf MIN	
Peel Strength	ASTM D-4632		15 lbs MIN	

Notes:

(1) All material used on the project must be from the sampled lot.

626.05 GCL INSTALLATION

The Contractor shall install the geosynthetic clay liner (GCL) in accordance with the plans and with these special provisions. In the event of conflict, the more stringent procedure shall apply unless approved otherwise by the Engineer and EPA.

626.05.1 Subgrade Preparation

The subgrade to receive GCLs shall be prepared and compacted in accordance with the project specifications and plans, and shall be smooth, firm, and free of: vegetation, construction debris, sticks, sharp rocks, ice, abrupt changes in elevation, standing water, cracks larger than one-quarter inch in width, and any other foreign matter that could contact the GCL.

626.05.2 Placement

1. Needle punched GCL shall be placed on top of the Compacted Clay Liner and on the site wide cap as shown on the plans.
2. GCL rolls should be delivered to the working area of the site in their original packaging. Immediately prior to deployment, the packaging should be carefully removed without damaging the GCL. The orientation of the GCL (i.e., which side faces up) should be in accordance with the Engineer's or manufacturer's recommendations. Unless otherwise specified, however, the GCL shall be installed such that the product name printed on one side of the GCL faces up.
3. Subgrade slope transitions will be uniformly curved and smooth prior to placement of the GCL. Care shall be taken when placing GCL that the subgrade is free of sharp changes in slope and uneven or variable radius curved transitions which may lead to unacceptable wrinkles or poor contact with the subgrade.
4. Equipment which could damage the GCL shall not be allowed to travel directly on it. If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.
5. Care must be taken to minimize the extent to which the GCL is dragged across the subgrade in order to avoid damage to the bottom surface of the GCL. A temporary geosynthetic subgrade covering commonly known as a skip sheet or rub sheet may be used to reduce friction damage during placement.
6. The GCL shall be placed so that seams are parallel to the direction of the maximum slope. Seams should be located at least 3 feet from the toe and crest of slopes steeper than 4H:1V.
7. All GCL panels should lie flat on the underlying surface, with no wrinkles or fold, especially at the exposed edges of the panels.

8. Only as much GCL shall be deployed as can be covered at the end of the working day with soil, a geomembrane, or a temporary waterproof tarpaulin. The GCL shall not be left uncovered overnight. If the GCL is hydrated when no confining stress is present, it will be removed and replaced. The Engineers, CQA inspector, and GCL supplier should be consulted for specific guidance if premature hydration occurs.

626.05.3 Anchorage

As directed by the Plans, the end of the GCL roll shall be placed in an anchor trench at the top of the slope. The front edge of the trench should be rounded so as to eliminate any sharp corners. Loose soil should be removed from the floor of the trench. The GCL should cover the entire trench floor and the rear trench wall.

626.05.4 Seaming

1. The GCL seams are constructed by overlapping their adjacent edges. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris. Supplemental bentonite is required if the GCL has one or more non-woven needle-punched geotextiles.
2. The minimum dimension of the longitudinal overlap should be 12 inches. End-of-roll overlapped seams should be similarly constructed, but the minimum overlap should measure 24 inches.
3. Seams at the ends of the panels should be constructed such that they are shingled in the direction of the grade to prevent the potential for runoff flow to enter the overlap zone.
4. Bentonite-enhanced seams are constructed between the overlapping adjacent panels and described above. The underlying edge of the longitudinal overlap is exposed and then a continuous bead of granular sodium bentonite is applied along a zone defined by the edge of the underlying panel and the 6-inch line. A similar bead of granular sodium bentonite is applied at the end-of-roll overlap. The bentonite shall be applied at a minimum application rate of one quarter pound per lineal foot.

626.05.5 Detail Work

1. The GCL shall be sealed around penetrations and embedded structures embedded in accordance with the design drawings and the GCL manufacturer.
2. Cutting the GCL should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the geotextile components of the GCL during the cutting process.

626.05.6 Damage Repair

If the GCL is damaged (torn, punctured, perforated, etc.) during installation, it may be possible to repair it by cutting a patch to fit over the damaged area. The patch shall be

obtained from a new GCL roll and shall be cut to size such that a minimum overlap of 12 inches is achieved around all of the damaged area. Dry bentonite or bentonite mastic shall be applied around the damaged area at a rate of one-half pound per square foot prior to placement of the patch. The Contractor may wish to use an adhesive to affix the patch in place so that it is not displaced during cover placement.

626.05.7 Cover Placement

1. Although direct vehicular contact with the GCL is to be avoided, lightweight, low ground pressure vehicles (such as 4-wheel all-terrain vehicles) may be used to facilitate the installation of geosynthetic material placed over the GCL. The GCL supplier or CQA engineer should be contacted with specific recommendations on the appropriate procedures in this situation.
2. When a textured geomembrane is installed over the GCL, a temporary geosynthetic covering known as a slip sheet or rub sheet should be used to minimize friction during placement and to allow the textured geomembrane to be more easily moved into its final position.
3. Cyclical wetting and drying of GCL covered only with geomembrane can cause overlap separation. A soil cover should be placed promptly over the geomembrane covering the GCL, but not directly on the GCL. Geomembranes should be covered with a white geotextile and/or operations layer without delay to minimize the intensity of wet-dry cycling. If there is the potential for unconfined cyclic wetting and drying over an extended period of time, the longitudinal seam overlaps should be increased based on the project engineer's recommendations.
4. To avoid seam separation, the GCL should not be put in excessive tension by the weight or expansion of textured geomembrane on steep slopes. The project Engineer should be consulted about the potential for GCL tension to develop.

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627.00 SOIL AMENDMENTS, SEEDBED PREPARATION, AND SEED MIX

Add the following new section.

627.01.1 Soil Amendments, Seedbed Preparation, And Seed Mix

- A. Topsoiling. Topsoil shall cover all embankment, backfill, site grading and exposed cut slope areas in accordance with Standard Specification 610. Application rates shall be a minimum of 6 inches at all sites unless otherwise designated in the specifications or on the Drawings.
- B. Seedbed Preparation. After the project site has been graded to final plan specifications the site to be seeded shall be cultivated to provide a uniform seedbed surface. The seedbed shall be cultivated sufficiently to reduce the soil to a state of good tilth when the soil particles on the surface are small enough to lie closely enough together to prevent the seed from being covered too deeply for optimum germination. Prior to executing the seeding, fertilizing, and mulching work items, the seedbed at all sites shall be prepared and conditioned so these items can most efficiently be completed in conformance with Standard Specification 610. The seeding, fertilizing, and mulching work items shall be executed only after the seedbed has been accepted by the Engineer.
- C. Seeding and Fertilizing. All areas at the sites disturbed in the execution of the work shall be seeded and fertilized. These areas include that acreage disturbed under the designated work items.

Other areas which are disturbed by the Contractor's operation, will also require seeding and fertilizing. Any such disturbed areas will be considered as site damage and will not be measured or considered for payment. The cost of this work shall be absorbed solely by the Contractor.

All disturbed areas shall be seeded with the designated Grass Mix. Two mixes are provided. One mix is for use on land designated for return to agricultural use and the other applies to all other disturbed areas.

The Contractor shall accomplish this work in accordance with the Fertilizing and Seeding Subsection and the Mulching Subsection of Standard Specification 610, and also in accordance with the provisions contained herein.

- 1. Fertilizer. Fertilizer shall be applied at the rates specified below. Exceptions will be made for seed drills that are capable of incorporating the fertilizer and seed directly into the seedbed uniformly at the specified rates. Fertilizer shall be applied to the prepared seedbed prior to seeding or mulching and shall be blended with the topsoil as called for in Standard Specification 610, or concurrently with the seed (as "no till" drills allow).

Fertilizer shall be applied to the prepared seedbed prior to seeding. The fertilizer shall be incorporated into the soil by discing, raking, or shallow plowing to the

full depth of the topsoil or to a maximum depth of 6 inches, whichever is less. Fertilizer shall be incorporated with equipment operated at right angles to the slope of the land.

All areas, except areas that will be returned to agricultural production within one year of project completion, shall be fertilized with a balanced inorganic chemical fertilizer with the following nutrients:

Composition 26-10-5

150 lbs/acre

All required fertilizer certificates shall be provided to the Engineer a minimum of three days prior to fertilizing. The certification shall include the guaranteed analysis of the fertilizer(s) stated in terms of the percentages of nitrogen (N), available phosphorus (P205) and potash (K20) in that order. The fertilizer specification may be changed by the Owner to a fertilizer mix based on specific site soil samples at no cost to the Owner.

2. Seed Certification. Seed certifications as required by Standard Specification 610 shall be submitted to the Engineer prior to any seeding. The Contractor shall also submit a copy of the bill or other documentation from the seed supplier showing actual bulk weights of the individual seed types combined in the mix. The required certifications and documentation shall be provided to the Engineer at least three days prior to seeding.
3. Seeding. The following application rates for seed are based on the drill seeding method. The seed mixture shall be uniformly distributed over the areas shown on project plans. All planting shall be done between October 15 and May 20 of a given year, except as specified in writing by the Owner. Seed shall be drilled at a depth of 1/2 inch utilizing a pasture or rangeland type drill (including custom seeders, furrow drills, disc drills or no-till drills) with a roller/cultipacker integral to the seed drill equipment. Broadcast seeding method will not be utilized on this project. Hydraulic seeding will be allowed only on areas too steep for drill seeding. Where the hydraulic seeding method is used, the application rates listed below must be doubled at no additional cost to the Owner.
4. Tracking. Tracking will be required only on areas where mulch tilling cannot be accomplished.

**DISTURBED AREAS DESIGNATED FOR RETURN TO
AGRICULTURAL PRODUCTION**

Common Name	Scientific Name	Variety	Seed Application Rate (PLS lbs/acre) ¹
Regreen	Triticum x Elytrigia	---	30
Total seeded species (PLS lbs/acre)¹			30

¹ PLS (Pure Live Seed) seeding rate is based on drill seed application.
PLS seeding rate will be doubled for broadcast or hydroseeded applications.

**DISTURBED AREAS NOT DESIGNATED FOR
RETURN TO AGRICULTURAL PRODUCTION**

Common Name	Scientific Name	Variety	Seed Application Rate (PLS lbs/acre) ¹
Streambank wheatgrass	Agropyron riparium	Sodar	2
Pubescent wheatgrass	Agropyron dasystachyum	Critana	2
Western wheatgrass	Agropyron smithii	Rosana	3
Bluebunch wheatgrass	Agropyron spicatum	Secar	3
Crested wheatgrass	Agropyron cristatum	Ephraim	2
Sideoats grama	Bouteloua curtipendula	Pierre	3
Regreen	Triticum x Elytrigia	---	10
Cicer milkvetch	Astragalus cicer	---	5
Total seeded species (PLS lbs/acre)¹			30

¹ PLS (Pure Live Seed) seeding rate is based on drill seed application.
PLS seeding rate will be doubled for broadcast or hydroseeded applications.

D. Tackifier. Tackifier shall be applied with all hydromulched areas at the manufacturer's recommended rate of forty (40) pounds per acre for slopes flatter than 2:1 and eighty (80) pounds per acre for slopes 2:1 or steeper.

1. Summer Erosion Control Procedure. In the event the construction is completed after April 30 but before October 15, the disturbed areas shall then be either mulched immediately with a vegetative mulch of straw or hay, applied at a rate of 4,000 pounds per acre or a soil stabilizer applied at the manufacturer's recommendation with a hydroseeder. The mulch shall be anchored into the seedbed as specified in Standard Specification 610.

A "no-till" drill with "no-till" coulters may be used to seed and fertilize directly into the mulched areas requiring permanent seeding after the October 15 date. After October 15, fertilizer shall be applied to the work areas at the application rate noted and incorporated into the soil as specified in Standard Specification 610. Seed shall then be applied by drilling methods only.

END OF DOCUMENT

DIVISION 700 - MATERIALS

SECTION 716 – GEOTEXTILE

717.01 GENERAL

Use 6 oz. Nonwoven High Survivability geotextile.

END OF DOCUMENT

APPENDIX B

DRAWINGS





ASARCO LLC EAST HELENA PLANT

CONCEPTUAL SITE WIDE COVER SYSTEM

JANUARY 2008

DRAWING LIST

DWG. NO.	TITLE
GENERAL SHEETS	
1	DRAWING INDEX & VICINITY MAP
2	LEGEND AND ABBREVIATION MAP
3	PLANT COVER SYSTEM - SITE PLAN
4	SITE WIDE PERMANENT COVER SYSTEM - GRADING PLAN
5	PROPOSED 2008 PERMANENT COVER SYSTEM - GRADING PLAN
6	DETAILS
7	
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REVISIONS	NO	BY	DATE	DESCRIPTION	REVISIONS	NO	BY	DATE	SCALE VERIFICATION BAR IS ONE INCH ON ORIGINAL DRAWING 0 1 IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	Project No.: 7054			Hydrometrics, Inc. Consulting Scientists and Engineers Helena, Montana 59601 3020 Buchanan Avenue (408) 443-4190		ASARCO LLC - EAST HELENA PLANT CONCEPTUAL SITE WIDE COVER SYSTEM		DRAWING INDEX & VICINITY MAP		DRAWING FILE NUMBER			
												DRAWN BY			SDP	1/17/07	705402H001.dwg		AUTOCAD 2004 DRAWING (DWG)		SHEET NUMBER	
												CHECKED BY			MWR	1/23/07					REV	
												APPROVED BY			MJO	1/24/07						
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GENERAL SYMBOLS		SITE SYMBOLS		MATERIALS IN SECTION AND PLAN		GENERAL ABBREVIATIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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"A" INDICATES SECTION IS SHOWN ON SAME SHEET.</div></div> <div><div></div><div>CONSTRUCTION NOTE</div></div> <div><div></div><div>SIGN NOTE</div></div> <div><div></div><div>SPECIFIC NOTE CALLOUT</div></div>		<p>SYMBOL IN PLAN</p> <p>DESCRIPTION</p> <p>UTILITY VAULT (TEL., ELEC.)</p> <p>POWER POLE</p> <p>TELEPHONE POLE</p> <p>HORIZONTAL CONTROL POINT</p> <p>SPOT ELEVATION</p> <p>FINISHED GRADE ELEVATION</p> <p>CONSTRUCTION STATIONING</p> <p>SLOPE PITCH</p> <p>POINT OF INTERSECTION</p> <p>CLEAN OUT</p> <p>SANITARY SEWER OR STORM SEWER MANHOLE</p> <p>STORM DRAIN CATCH BASIN</p> <p>CONCRETE REACTION BLOCKING</p> <p>FIRE HYDRANT</p> <p>LIGHT POLE W/ LUMINAIRE</p> <p>SURVEY MONUMENT OR BENCHMARK</p> <p>TRAFFIC CONTROL SIGN</p> <p>TRAFFIC CONTROL BARRICADE</p> <p>EXISTING PUMP</p> <p>PROPOSED PUMP</p> <p>EMBANKMENT SLOPE (SLOPE DARTS INDICATE DOWNSLOPE)</p> <p>WIRE FENCE OR FIELD FENCE</p> <p>CHAINLINK FENCE</p> <p>WOODEN FENCE</p> <p>BREAKLINE</p> <p>EXISTING INTERMEDIATE GROUND SURFACE CONTOUR</p> <p>EXISTING INDEX GROUND SURFACE CONTOUR</p> <p>PROPOSED INTERMEDIATE GROUND SURFACE CONTOUR</p> <p>PROPOSED INDEX GROUND SURFACE CONTOUR</p> <p>DRAINAGE FLOW</p> <p>DRAINAGE DITCH</p> <p>PERENNIAL/GENERALIZED STREAM</p> <p>EPHEMERAL STREAM</p> <p>PROPERTY LINE</p> <p>RIGHT OF WAY LINE</p> <p>CENTERLINE</p> <p>TELEPHONE LINE</p> <p>POWER LINE</p> <p>GAS PIPELINE</p> <p>SANITARY SEWER</p> <p>STORM DRAIN</p> <p>TV CABLE LINE</p> <p>WATER LINE</p> <p>EXISTING GROUND SURFACE (IN SECTION)</p> <p>PROPOSED GROUND SURFACE (IN SECTION)</p> <p>GEONET LINER</p> <p>PROPERTY BOUNDARY</p> <p>SITE CAP BOUNDARY</p>		<p>NOTE: BOXES WITHOUT HATCH PATTERNS ARE NOT APPLICABLE</p> <table><tr><th>PLAN VIEW EXISTING/PROPOSED</th><th>SECTION VIEW EXISTING/PROPOSED</th><th>DESCRIPTION</th></tr><tr><td></td><td></td><td>DEMOLITION</td></tr><tr><td></td><td></td><td>PRECAST CONCRETE</td></tr><tr><td></td><td></td><td>CAST-IN-PLACE CONCRETE</td></tr><tr><td></td><td></td><td>MORTAR, GROUT OR PLASTER</td></tr><tr><td></td><td></td><td>METAL PLATE OR CASTING</td></tr><tr><td></td><td></td><td>ASPHALT/CONCRETE PAVING</td></tr><tr><td></td><td></td><td>NATURAL GROUND SOIL OR EARTH</td></tr><tr><td></td><td></td><td>COMPACTED FILL OR BACKFILL</td></tr><tr><td></td><td></td><td>BEDROCK</td></tr><tr><td></td><td></td><td>TOPSOIL OR RECLAMATION COVER</td></tr><tr><td></td><td></td><td>COMPACTED CLAY OR BENTONITE</td></tr></table> <p>STANDARD MATERIAL LAYERS</p> <table><tr><th>SURFACE LAYERS</th><th>DRAINAGE LAYERS</th></tr><tr><td> TOP SOIL</td><td> GRAVEL</td></tr><tr><td> CONCRETE</td><td> SAND</td></tr><tr><td> ASPHALT CONCRETE</td><td> SYNTHETIC DRAIN (SECTION)</td></tr><tr><td> FILL LAYER (BORROW SOIL)</td><td> SYNTHETIC DRAIN (PLAN)</td></tr><tr><td> SOIL (CLASSIFIED)</td><td></td></tr><tr><td> BUILDINGS</td><td></td></tr><tr><td> SOIL</td><td></td></tr></table> <p>BARRIER LAYERS</p> <table><tr><td> COMPACTED CLAY LINER</td></tr><tr><td> GEOSYNTHETIC CLAY LINER</td></tr><tr><td> FLEXIBLE MEMBRANE LINER</td></tr><tr><td> PETROTAC LINER</td></tr></table> <p>SOURCE LAYERS</p> <table><tr><td> WASTE SOIL GENERIC</td></tr></table> <p>UNDERLAYING LAYERS</p> <table><tr><td> SLAG</td></tr><tr><td> NATIVE SOILS</td></tr></table> <p>PROTECTIVE LAYERS</p> <table><tr><td> FILL LAYER (BORROW SOIL)</td></tr><tr><td> SOIL (CLASSIFIED)</td></tr></table> <p>SEPARATION LAYERS</p> <table><tr><td> GEOTEXTILE LAYER (WOVEN)</td></tr><tr><td> GEOTEXTILE LAYER (NON-WOVEN)</td></tr><tr><td> SAND</td></tr><tr><td> SOIL (CLASSIFIED)</td></tr></table>		PLAN VIEW EXISTING/PROPOSED	SECTION VIEW EXISTING/PROPOSED	DESCRIPTION			DEMOLITION			PRECAST CONCRETE			CAST-IN-PLACE CONCRETE			MORTAR, GROUT OR PLASTER			METAL PLATE OR CASTING			ASPHALT/CONCRETE PAVING			NATURAL GROUND SOIL OR EARTH			COMPACTED FILL OR BACKFILL			BEDROCK			TOPSOIL OR RECLAMATION COVER			COMPACTED CLAY OR BENTONITE	SURFACE LAYERS	DRAINAGE LAYERS	TOP SOIL	GRAVEL	CONCRETE	SAND	ASPHALT CONCRETE	SYNTHETIC DRAIN (SECTION)	FILL LAYER (BORROW SOIL)	SYNTHETIC DRAIN (PLAN)	SOIL (CLASSIFIED)		BUILDINGS		SOIL		COMPACTED CLAY LINER	GEOSYNTHETIC CLAY LINER	FLEXIBLE MEMBRANE LINER	PETROTAC LINER	WASTE SOIL GENERIC	SLAG	NATIVE SOILS	FILL LAYER (BORROW SOIL)	SOIL (CLASSIFIED)	GEOTEXTILE LAYER (WOVEN)	GEOTEXTILE LAYER (NON-WOVEN)	SAND	SOIL (CLASSIFIED)	<table><tr><td>A</td><td>AIR, AERATOR</td><td>F</td><td>FILT</td><td>FILTER</td><td>P</td><td>PC</td><td>PIPE COLUMN</td></tr><tr><td>AB</td><td>ANCHOR BOLT</td><td>FLTR</td><td>FILTER FABRIC</td><td>PCV</td><td>PRESSURE CONTROL VALVE</td><td>PE</td><td>PLAIN END, PRESSURE ELEMENT, PRIMARY EFFLUENT</td></tr><tr><td>ABN</td><td>ABANDON IN PLACE</td><td>FLM</td><td>FLAME</td><td>PERF</td><td>PERFORATED</td><td>PF</td><td>PROPELLER FAN</td></tr><tr><td>ABND</td><td>ABANDONED</td><td>FLR</td><td>FLOOR</td><td>PG</td><td>PRESSURE GAGE</td><td>PI</td><td>POINT OF INTERSECTION, PRIMARY INFLUENT</td></tr><tr><td>ABS</td><td>ACRYLONITRILE BUTADIENE STYRENE</td><td>FM</td><td>FORCE MAIN, FLOW METER</td><td>PL</td><td>PLATE, PLACE, PLASTIC</td><td>P/L</td><td>PROPERTY LINE</td></tr><tr><td>AC</td><td>AIR COMPRESSOR, AIR CONDITIONER(ING)</td><td>FLM</td><td>FLEXIBLE MEMBRANE LINER</td><td>PP</td><td>POWER PANEL</td><td>PR</td><td>PRIMARY</td></tr><tr><td>ACI</td><td>AMERICAN CONCRETE INSTITUTE</td><td>FOB</td><td>FINE ORE BIN BUILDING</td><td>FT</td><td>FEET, FOOT, FLOW TRANSMITTER</td><td>PROJ</td><td>PROJECTION</td></tr><tr><td>ACP</td><td>ASPHALTIC CONCRETE</td><td>FOT</td><td>FLAT ON TOP</td><td>FTG</td><td>FOOTING</td><td>PRV</td><td>PRESSURE REDUCING VALVE</td></tr><tr><td>ADDN</td><td>ADDITION, ADDITIONAL</td><td>FPT</td><td>FEMALE PIPE THREAD</td><td>PS</td><td>PIPE SUPPORT</td><td>PSF</td><td>POUNDS PER SQUARE FOOT</td></tr><tr><td>ADS</td><td>ADVANCED DRAINAGE SYSTEMS (TM)</td><td>FRP</td><td>FIBERGLASS REINFORCED PLASTIC</td><td>PSI</td><td>POUNDS PER SQUARE INCH</td><td>PSL</td><td>PIPE SLEEVE</td></tr><tr><td>AFF</td><td>ABOVE FINISH FLOOR</td><td>FSL</td><td>FLOW SWITCH</td><td>PT</td><td>PRESSURE TRANSMITTER</td><td>PV</td><td>PLUG VALVE</td></tr><tr><td>AFM</td><td>AIR FLOW METER</td><td>FT</td><td>FEET, FOOT, FLOW TRANSMITTER</td><td>PVC</td><td>POLYVINYL CHLORIDE (PIPE)</td><td>PVMT</td><td>PAVEMENT</td></tr><tr><td>AGG</td><td>AGGREGATE</td><td>FTG</td><td>FOOTING</td><td>PW</td><td>POTABLE WATER</td><td></td><td></td></tr><tr><td>AMP</td><td>AMPERE</td><td></td><td></td><td>R</td><td></td><td>R</td><td>RADIUS, RIGHT</td></tr><tr><td>ATB</td><td>ASPHALT TREATED BASE</td><td></td><td></td><td>GA</td><td>GAGE</td><td>RB</td><td>ROOF BEAM</td></tr><tr><td>AHU</td><td>AIR HANDLING UNIT</td><td></td><td></td><td>GAL</td><td>GALLON</td><td>RCP</td><td>REINFORCED CONCRETE PIPE</td></tr><tr><td>ALT</td><td>ALTERNATE</td><td></td><td></td><td>GALV</td><td>GALVANIZED</td><td>RD</td><td>ROOF DRAIN, ROLLUP DOOR</td></tr><tr><td>ALUM</td><td>ALUMINUM</td><td></td><td></td><td>GALVS</td><td>GALVANIZED STEEL</td><td>REL</td><td>ROOF DRAIN LEADER</td></tr><tr><td>APPROX</td><td>APPROXIMATE</td><td></td><td></td><td>GCL</td><td>GEOSYNTHETIC CLAY LINER</td><td>RECIRC</td><td>RECIRCULATION</td></tr><tr><td>AR</td><td>AIR RELEASE</td><td></td><td></td><td>GEONET</td><td>GEOTEXTILE</td><td>RECT</td><td>RECTANGULAR</td></tr><tr><td>ASSY</td><td>ASSEMBLY</td><td></td><td></td><td>GEOTX</td><td>GEOTEXTILE</td><td>RED</td><td>REDUCER</td></tr><tr><td>AVG</td><td>AVERAGE</td><td></td><td></td><td>GPM</td><td>GALLONS PER MINUTE</td><td>REF</td><td>REFERENCE</td></tr><tr><td>B</td><td></td><td>G</td><td></td><td>GND</td><td>GROUND</td><td>REIN</td><td>REINFORCE(ING)</td></tr><tr><td>BCV</td><td>BALL CHECK VALVE</td><td></td><td></td><td>GRG</td><td>GRATING</td><td>REQD</td><td>REQUIRE(ED)</td></tr><tr><td>BF</td><td>BLIND FLANGE</td><td></td><td></td><td>GRV</td><td>GRAVITY ROOF VENTILATOR</td><td>RM</td><td>ROOM(S)</td></tr><tr><td>BFV</td><td>BUTTERFLY VALVE</td><td></td><td></td><td>GS</td><td>GRATING SUPPORT</td><td>R/W</td><td>RIGHT OF WAY</td></tr><tr><td>BGS</td><td>BELOW GROUND SURFACE</td><td></td><td></td><td>GSP</td><td>GALVANIZED STEEL PIPE</td><td>R&R</td><td>REMOVE AND REPLACE PER ORIGINAL</td></tr><tr><td>BTUM</td><td>BITUMINOUS</td><td></td><td></td><td>GV</td><td>GATE VALVE</td><td>R&S</td><td>REMOVE AND SALVAGE TO OWNER</td></tr><tr><td>BLDG</td><td>BUILDING</td><td></td><td></td><td>GWB</td><td>GYPSUM WALLBOARD</td><td>RV</td><td>ROOF VENTILATOR</td></tr><tr><td>BM</td><td>BENCHMARK, BEAM</td><td></td><td></td><td>H</td><td></td><td>S</td><td></td></tr><tr><td>BGG</td><td>BOTTOM OF GRILL</td><td></td><td></td><td>H</td><td>HATCH, HIGH</td><td>SA</td><td>SOURCE AREA</td></tr><tr><td>BOP</td><td>BOTTOM OF PIPE</td><td></td><td></td><td>HB</td><td>HOSE BIBB</td><td>SAM</td><td>SAMPLE</td></tr><tr><td>BP</td><td>BACKFLOW PREVENTOR</td><td></td><td></td><td>HDPE</td><td>HIGH DENSITY POLYETHYLENE</td><td>SCH</td><td>SCHEDULE</td></tr><tr><td>BRK</td><td>BRICK</td><td></td><td></td><td>HC</td><td>HEATING COIL</td><td>SD</td><td>STORM DRAIN</td></tr><tr><td>BTW</td><td>BETWEEN</td><td></td><td></td><td>HH</td><td>HEX HEAD</td><td>SEC</td><td>SECTION</td></tr><tr><td>BSP</td><td>BLACK STEEL PIPE</td><td></td><td></td><td>HK</td><td>HOOK</td><td>SF</td><td>SUPPLY FAN</td></tr><tr><td>BST</td><td>BITUMINOUS SURFACE TREATMENT</td><td></td><td></td><td>HM</td><td>HOLLOW METAL</td><td>SHT</td><td>SHEET</td></tr><tr><td>BU</td><td>BELL UP</td><td></td><td></td><td>HMC</td><td>HARNESSED MECHANICAL COUPLING</td><td>SIM</td><td>SIMILAR</td></tr><tr><td>BV</td><td>BALL VALVE</td><td></td><td></td><td>HORIZ</td><td>HORIZONTAL</td><td>SL</td><td>SLOPE</td></tr><tr><td>C</td><td></td><td>I</td><td></td><td>HP</td><td>HIGH POINT</td><td>SPEC</td><td>SPECIFICATION</td></tr><tr><td>C&G</td><td>CURB & GUTTER</td><td></td><td></td><td>HR</td><td>HANDRAIL</td><td>SQ</td><td>SQUARE</td></tr><tr><td>CB</td><td>CATCH BASIN</td><td></td><td></td><td>HS</td><td>HEADED STUD</td><td>SRF</td><td>SEDIMENT REMOVAL FACILITY</td></tr><tr><td>CCL</td><td>COMPACTED CLAY LINER</td><td></td><td></td><td>HT</td><td>HEIGHT</td><td>SS</td><td>SANITARY SEWER, STAINLESS STEEL</td></tr><tr><td>CD</td><td>CONTROL DENSITY FILL</td><td></td><td></td><td>HV</td><td>HOSE VALVE</td><td>STA</td><td>STATION</td></tr><tr><td>CF</td><td>CUBIC FEET</td><td></td><td></td><td>HVAC</td><td>HEATING, VENTILATION & AIR CONDITIONING</td><td>STD</td><td>STANDARD</td></tr><tr><td>CFM</td><td>CUBIC FEET PER MINUTE</td><td></td><td></td><td>HW</td><td>HOT WATER</td><td>STR</td><td>STIRRUP</td></tr><tr><td>CFS</td><td>CUBIC FEET PER SECOND</td><td></td><td></td><td>HWL</td><td>HIGH WATER LEVEL</td><td>STL</td><td>STEEL</td></tr><tr><td>CI</td><td>CAST IRON</td><td></td><td></td><td>J</td><td></td><td>S</td><td></td></tr><tr><td>CIP</td><td>CAST IRON PIPE</td><td></td><td></td><td>JAN</td><td>JANITOR</td><td>SV</td><td>SOLENOID VALVE</td></tr><tr><td>CJ</td><td>CONSTRUCTION JOINT</td><td></td><td></td><td>JB</td><td>JUNCTION BOX</td><td>SWM</td><td>CITY OF TACOMA/PERCE COUNTY STORM WATER MANAGEMENT MANUAL SQUARE YARD</td></tr><tr><td>CL</td><td>CENTERLINE</td><td></td><td></td><td>JT</td><td>JOINT</td><td>SY</td><td></td></tr><tr><td>CLG</td><td>CEILING</td><td></td><td></td><td>K</td><td></td><td>T</td><td></td></tr><tr><td>CLR</td><td>CLEAR, CLEARANCE</td><td></td><td></td><td>KGV</td><td>KNIFE GATE VALVE</td><td>T</td><td>TREADS</td></tr><tr><td>CMP</td><td>CORRUGATED METAL PIPE</td><td></td><td></td><td>L</td><td></td><td>TBM</td><td>TEMPORARY BENCHMARK</td></tr><tr><td>CNU</td><td>CONCRETE MASONRY UNIT</td><td></td><td></td><td>L</td><td>LEFT</td><td>TC</td><td>TOP OF CURB</td></tr><tr><td>CO</td><td>CLEAN OUT</td><td></td><td></td><td>LB</td><td>LOAD</td><td>TCV</td><td>TEMPERATURE CONTROL VALVE</td></tr><tr><td>COL</td><td>COLUMN</td><td></td><td></td><td>LDPE</td><td>LOW DENSITY POLYETHYLENE</td><td>TE</td><td>TOP ELEVATION</td></tr><tr><td>CONN</td><td>CONNECTION</td><td></td><td></td><td>LL</td><td>LIVE LOAD</td><td>TEL</td><td>TELEPHONE</td></tr><tr><td>CONC</td><td>CONCRETE</td><td></td><td></td><td>LAB</td><td>LABORATORY</td><td>TEMP</td><td>TEMPORARY</td></tr><tr><td>CONST</td><td>CONSTRUCTION</td><td></td><td></td><td>LAV</td><td>LAVATORY</td><td>TH</td><td>TEST HOLE</td></tr><tr><td>CONT</td><td>CONTINUOUS, CONTINUATION</td><td></td><td></td><td>LE</td><td>LEVEL ELEMENT</td><td>THD</td><td>THREADED</td></tr><tr><td>CP</td><td>CONCRETE PIPE</td><td></td><td></td><td>LF</td><td>LINEAR FOOT</td><td>THK</td><td>THICK</td></tr><tr><td>CPLD</td><td>CAST IRON SOIL PIPE</td><td></td><td></td><td>LS</td><td>LEVEL SWITCH</td><td>TOC</td><td>TOP OF CASING</td></tr><tr><td>CSP</td><td>CAST IRON SOIL PIPE</td><td></td><td></td><td>LT</td><td>LEVEL TRANSMITTER</td><td>TOD</td><td>TOP OF DECK</td></tr><tr><td>CS</td><td>CHLORINE SOLUTION</td><td></td><td></td><td>LWL</td><td>LOW WATER LEVEL</td><td>TOT</td><td>TOP OF FOOTING</td></tr><tr><td>CTR</td><td>CENTER</td><td></td><td></td><td>M</td><td></td><td>TOS</td><td>TOP OF SUPPORT</td></tr><tr><td>CU</td><td>COPPER</td><td></td><td></td><td>MAINT</td><td>MAINTENANCE</td><td>TOW</td><td>TOP OF WALL</td></tr><tr><td>CW</td><td>COLD WATER</td><td></td><td></td><td>MATL</td><td>MATERIAL</td><td>TS</td><td>TUBULAR STEEL</td></tr><tr><td>CV</td><td>CHECK VALVE</td><td></td><td></td><td>MAX</td><td>MAXIMUM</td><td>TT</td><td>TEMPERATURE TRANSMITTER</td></tr><tr><td>CY</td><td>CUBIC YARD</td><td></td><td></td><td>MB</td><td>MACHINE BOLT</td><td>TYP</td><td>TYPICAL</td></tr><tr><td>D</td><td></td><td>N</td><td></td><td>MCC</td><td>MOTOR CONTROL CENTER</td><td>T&B</td><td>TOP AND BOTTOM</td></tr><tr><td>DEG</td><td>DEGREE</td><td></td><td></td><td>MDM</td><td>MODIFIED DOUBLE MECHANICAL JOINT</td><td>U</td><td></td></tr><tr><td>DET</td><td>DETAIL</td><td></td><td></td><td>MECH</td><td>MECHANICAL</td><td>UH</td><td>UNIT HEATER</td></tr><tr><td>DIA</td><td>DIAMETER</td><td></td><td></td><td>MED</td><td>MEDIUM</td><td>UK</td><td>UNKNOWN</td></tr><tr><td>DM</td><td>DIMENSION</td><td></td><td></td><td>MFR</td><td>MANUFACTURER</td><td>V</td><td></td></tr><tr><td>DIFF</td><td>DIFFUSER</td><td></td><td></td><td>MH</td><td>MANHOLE</td><td>VAC</td><td>VACUUM</td></tr><tr><td>DI</td><td>DUCTILE IRON</td><td></td><td></td><td>MISC</td><td>MISCELLANEOUS</td><td>VAR</td><td>VARNISH</td></tr><tr><td>DISCH</td><td>DISCHARGE</td><td></td><td></td><td>MIN</td><td>MINIMUM</td><td>VO</td><td>VOLUME DAMPER</td></tr><tr><td>DIST</td><td>DISTANCE</td><td></td><td></td><td>MO</td><td>MASONRY OPENING</td><td>VERT</td><td>VERTICAL</td></tr><tr><td>DL</td><td>DEAD LOAD</td><td></td><td></td><td>MOD</td><td>MODIFIED, MODIFICATION</td><td>VIF</td><td>VERIFY IN FIELD</td></tr><tr><td>DMJ</td><td>DOUBLE MECHANICAL JOINT</td><td></td><td></td><td>MROGB</td><td>MOISTURE RESISTANT GYPSUM WALLBOARD</td><td>VTR</td><td>VENT THRU ROOF</td></tr><tr><td>DN</td><td>DOWN</td><td></td><td></td><td>MSE</td><td>MECHANICALLY STABILIZED EARTH</td><td>W</td><td></td></tr><tr><td>DP</td><td>DRAIN PUMP</td><td></td><td></td><td>MTL</td><td>METAL</td><td>W</td><td>WATER, WINDOW, WIDE, WEST</td></tr><tr><td>DR</td><td>DRAIN</td><td></td><td></td><td>E</td><td></td><td>WC</td><td>WATER CLOSET</td></tr><tr><td>DS</td><td>DUCT SUPPORT</td><td></td><td></td><td>EA</td><td>ELECTRICAL CONDUIT, EAST</td><td>WD</td><td>WOOD</td></tr><tr><td>DV</td><td>DIAPHRAGM VALVE</td><td></td><td></td><td>ECC</td><td>ECCENTRIC</td><td>WH</td><td>WATER HEATER</td></tr><tr><td>DWG</td><td>DRAWING</td><td></td><td></td><td>EE</td><td>EACH END</td><td>WP</td><td>WATERPROOF(ED),(ING)</td></tr><tr><td>E</td><td></td><td>N</td><td></td><td>EF</td><td>EXHAUST FAN, EACH FACE</td><td>WS</td><td>WATERSTOP</td></tr><tr><td>EA</td><td>ELECTRICAL CONDUIT, EAST</td><td></td><td></td><td>EFFL</td><td>EFFLUENT</td><td>WSP</td><td>WELDED STEEL PIPE</td></tr><tr><td>ECC</td><td>ECCENTRIC</td><td></td><td></td><td>EJ</td><td>EXPANSION JOINT</td><td>WT</td><td>WEIGHT</td></tr><tr><td>EE</td><td>EACH END</td><td></td><td></td><td>ELM</td><td>EXPANSION JOINT MATERIAL</td><td>WWF</td><td>WELDED WIRE FABRIC</td></tr><tr><td>EF</td><td>EXHAUST FAN, EACH FACE</td><td></td><td></td><td>EL</td><td>ELEVATION</td><td>W/O</td><td>WITH</td></tr><tr><td>EFFL</td><td>EFFLUENT</td><td></td><td></td><td>ELB</td><td>ELBOW</td><td>W/O</td><td>WITHOUT</td></tr><tr><td>EJ</td><td>EXPANSION JOINT</td><td></td><td></td><td>ELEC</td><td>ELECTRICAL</td><td>X</td><td></td></tr><tr><td>ELM</td><td>EXPANSION JOINT MATERIAL</td><td></td><td></td><td>EMH</td><td>ELECTRICAL MANHOLE</td><td>XFMR</td><td>TRANSFORMER</td></tr><tr><td>EL</td><td>ELEVATION</td><td></td><td></td><td>ENGR</td><td>ENGINEER</td><td></td><td></td></tr><tr><td>ELB</td><td>ELBOW</td><td></td><td></td><td>EQUIP</td><td>EQUIPMENT</td><td></td><td></td></tr><tr><td>ELEC</td><td>ELECTRICAL</td><td></td><td></td><td>EQ</td><td>EQUAL</td><td></td><td></td></tr><tr><td>EMH</td><td>ELECTRICAL MANHOLE</td><td></td><td></td><td>EUH</td><td>ELECTRIC UNIT HEATER</td><td></td><td></td></tr><tr><td>ENGR</td><td>ENGINEER</td><td></td><td></td><td>EW</td><td>ELECTRIC WATER HEATER</td><td></td><td></td></tr><tr><td>EQUIP</td><td>EQUIPMENT</td><td></td><td></td><td>EXT</td><td>EXISTING</td><td></td><td></td></tr><tr><td>EQ</td><td>EQUAL</td><td></td><td></td><td>EXP</td><td>EXPANSION</td><td></td><td></td></tr><tr><td>EUH</td><td>ELECTRIC UNIT HEATER</td><td></td><td></td><td>EXT</td><td>EXTERIOR, EXTERNAL</td><td></td><td></td></tr><tr><td>EW</td><td>ELECTRIC WATER HEATER</td><td></td><td></td><td>F</td><td></td><td>F</td><td></td></tr><tr><td>EXT</td><td>EXISTING</td><td></td><td></td><td>FAB</td><td>FABRICATION</td><td></td><td></td></tr><tr><td>EXP</td><td>EXPANSION</td><td></td><td></td><td>FB</td><td>FLOOR BEAM</td><td></td><td></td></tr><tr><td>EXT</td><td>EXTERIOR, EXTERNAL</td><td></td><td></td><td>FC</td><td>FLUSHING CONNECTION, FAN COIL</td><td></td><td></td></tr><tr><td>F</td><td></td><td>F</td><td></td><td>FDN</td><td>FOUNDATION</td><td></td><td></td></tr><tr><td>FAB</td><td>FABRICATION</td><td></td><td></td><td>FE</td><td>FIRE EXTINGUISHER, FLOW ELEMENT</td><td></td><td></td></tr><tr><td>FB</td><td>FLOOR BEAM</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>FC</td><td>FLUSHING CONNECTION, FAN COIL</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>FDN</td><td>FOUNDATION</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>FE</td><td>FIRE EXTINGUISHER, FLOW ELEMENT</td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>		A	AIR, AERATOR	F	FILT	FILTER	P	PC	PIPE COLUMN	AB	ANCHOR BOLT	FLTR	FILTER FABRIC	PCV	PRESSURE CONTROL VALVE	PE	PLAIN END, PRESSURE ELEMENT, PRIMARY EFFLUENT	ABN	ABANDON IN PLACE	FLM	FLAME	PERF	PERFORATED	PF	PROPELLER FAN	ABND	ABANDONED	FLR	FLOOR	PG	PRESSURE GAGE	PI	POINT OF INTERSECTION, PRIMARY INFLUENT	ABS	ACRYLONITRILE BUTADIENE STYRENE	FM	FORCE MAIN, FLOW METER	PL	PLATE, PLACE, PLASTIC	P/L	PROPERTY LINE	AC	AIR COMPRESSOR, AIR CONDITIONER(ING)	FLM	FLEXIBLE MEMBRANE LINER	PP	POWER PANEL	PR	PRIMARY	ACI	AMERICAN CONCRETE INSTITUTE	FOB	FINE ORE BIN BUILDING	FT	FEET, FOOT, FLOW TRANSMITTER	PROJ	PROJECTION	ACP	ASPHALTIC CONCRETE	FOT	FLAT ON TOP	FTG	FOOTING	PRV	PRESSURE REDUCING VALVE	ADDN	ADDITION, ADDITIONAL	FPT	FEMALE PIPE THREAD	PS	PIPE SUPPORT	PSF	POUNDS PER SQUARE FOOT	ADS	ADVANCED DRAINAGE SYSTEMS (TM)	FRP	FIBERGLASS REINFORCED PLASTIC	PSI	POUNDS PER SQUARE INCH	PSL	PIPE SLEEVE	AFF	ABOVE FINISH FLOOR	FSL	FLOW SWITCH	PT	PRESSURE TRANSMITTER	PV	PLUG VALVE	AFM	AIR FLOW METER	FT	FEET, FOOT, FLOW TRANSMITTER	PVC	POLYVINYL CHLORIDE (PIPE)	PVMT	PAVEMENT	AGG	AGGREGATE	FTG	FOOTING	PW	POTABLE WATER			AMP	AMPERE			R		R	RADIUS, RIGHT	ATB	ASPHALT TREATED BASE			GA	GAGE	RB	ROOF BEAM	AHU	AIR HANDLING UNIT			GAL	GALLON	RCP	REINFORCED CONCRETE PIPE	ALT	ALTERNATE			GALV	GALVANIZED	RD	ROOF DRAIN, ROLLUP DOOR	ALUM	ALUMINUM			GALVS	GALVANIZED STEEL	REL	ROOF DRAIN LEADER	APPROX	APPROXIMATE			GCL	GEOSYNTHETIC CLAY LINER	RECIRC	RECIRCULATION	AR	AIR RELEASE			GEONET	GEOTEXTILE	RECT	RECTANGULAR	ASSY	ASSEMBLY			GEOTX	GEOTEXTILE	RED	REDUCER	AVG	AVERAGE			GPM	GALLONS PER MINUTE	REF	REFERENCE	B		G		GND	GROUND	REIN	REINFORCE(ING)	BCV	BALL CHECK VALVE			GRG	GRATING	REQD	REQUIRE(ED)	BF	BLIND FLANGE			GRV	GRAVITY ROOF VENTILATOR	RM	ROOM(S)	BFV	BUTTERFLY VALVE			GS	GRATING SUPPORT	R/W	RIGHT OF WAY	BGS	BELOW GROUND SURFACE			GSP	GALVANIZED STEEL PIPE	R&R	REMOVE AND REPLACE PER ORIGINAL	BTUM	BITUMINOUS			GV	GATE VALVE	R&S	REMOVE AND SALVAGE TO OWNER	BLDG	BUILDING			GWB	GYPSUM WALLBOARD	RV	ROOF VENTILATOR	BM	BENCHMARK, BEAM			H		S		BGG	BOTTOM OF GRILL			H	HATCH, HIGH	SA	SOURCE AREA	BOP	BOTTOM OF PIPE			HB	HOSE BIBB	SAM	SAMPLE	BP	BACKFLOW PREVENTOR			HDPE	HIGH DENSITY POLYETHYLENE	SCH	SCHEDULE	BRK	BRICK			HC	HEATING COIL	SD	STORM DRAIN	BTW	BETWEEN			HH	HEX HEAD	SEC	SECTION	BSP	BLACK STEEL PIPE			HK	HOOK	SF	SUPPLY FAN	BST	BITUMINOUS SURFACE TREATMENT			HM	HOLLOW METAL	SHT	SHEET	BU	BELL UP			HMC	HARNESSED MECHANICAL COUPLING	SIM	SIMILAR	BV	BALL VALVE			HORIZ	HORIZONTAL	SL	SLOPE	C		I		HP	HIGH POINT	SPEC	SPECIFICATION	C&G	CURB & GUTTER			HR	HANDRAIL	SQ	SQUARE	CB	CATCH BASIN			HS	HEADED STUD	SRF	SEDIMENT REMOVAL FACILITY	CCL	COMPACTED CLAY LINER			HT	HEIGHT	SS	SANITARY SEWER, STAINLESS STEEL	CD	CONTROL DENSITY FILL			HV	HOSE VALVE	STA	STATION	CF	CUBIC FEET			HVAC	HEATING, VENTILATION & AIR CONDITIONING	STD	STANDARD	CFM	CUBIC FEET PER MINUTE			HW	HOT WATER	STR	STIRRUP	CFS	CUBIC FEET PER SECOND			HWL	HIGH WATER LEVEL	STL	STEEL	CI	CAST IRON			J		S		CIP	CAST IRON PIPE			JAN	JANITOR	SV	SOLENOID VALVE	CJ	CONSTRUCTION JOINT			JB	JUNCTION BOX	SWM	CITY OF TACOMA/PERCE COUNTY STORM WATER MANAGEMENT MANUAL SQUARE YARD	CL	CENTERLINE			JT	JOINT	SY		CLG	CEILING			K		T		CLR	CLEAR, CLEARANCE			KGV	KNIFE GATE VALVE	T	TREADS	CMP	CORRUGATED METAL PIPE			L		TBM	TEMPORARY BENCHMARK	CNU	CONCRETE MASONRY UNIT			L	LEFT	TC	TOP OF CURB	CO	CLEAN OUT			LB	LOAD	TCV	TEMPERATURE CONTROL VALVE	COL	COLUMN			LDPE	LOW DENSITY POLYETHYLENE	TE	TOP ELEVATION	CONN	CONNECTION			LL	LIVE LOAD	TEL	TELEPHONE	CONC	CONCRETE			LAB	LABORATORY	TEMP	TEMPORARY	CONST	CONSTRUCTION			LAV	LAVATORY	TH	TEST HOLE	CONT	CONTINUOUS, CONTINUATION			LE	LEVEL ELEMENT	THD	THREADED	CP	CONCRETE PIPE			LF	LINEAR FOOT	THK	THICK	CPLD	CAST IRON SOIL PIPE			LS	LEVEL SWITCH	TOC	TOP OF CASING	CSP	CAST IRON SOIL PIPE			LT	LEVEL TRANSMITTER	TOD	TOP OF DECK	CS	CHLORINE SOLUTION			LWL	LOW WATER LEVEL	TOT	TOP OF FOOTING	CTR	CENTER			M		TOS	TOP OF SUPPORT	CU	COPPER			MAINT	MAINTENANCE	TOW	TOP OF WALL	CW	COLD WATER			MATL	MATERIAL	TS	TUBULAR STEEL	CV	CHECK VALVE			MAX	MAXIMUM	TT	TEMPERATURE TRANSMITTER	CY	CUBIC YARD			MB	MACHINE BOLT	TYP	TYPICAL	D		N		MCC	MOTOR CONTROL CENTER	T&B	TOP AND BOTTOM	DEG	DEGREE			MDM	MODIFIED DOUBLE MECHANICAL JOINT	U		DET	DETAIL			MECH	MECHANICAL	UH	UNIT HEATER	DIA	DIAMETER			MED	MEDIUM	UK	UNKNOWN	DM	DIMENSION			MFR	MANUFACTURER	V		DIFF	DIFFUSER			MH	MANHOLE	VAC	VACUUM	DI	DUCTILE IRON			MISC	MISCELLANEOUS	VAR	VARNISH	DISCH	DISCHARGE			MIN	MINIMUM	VO	VOLUME DAMPER	DIST	DISTANCE			MO	MASONRY OPENING	VERT	VERTICAL	DL	DEAD LOAD			MOD	MODIFIED, MODIFICATION	VIF	VERIFY IN FIELD	DMJ	DOUBLE MECHANICAL JOINT			MROGB	MOISTURE RESISTANT GYPSUM WALLBOARD	VTR	VENT THRU 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